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The status of the leafy spurge numbering system

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At the Dickinson Symposium, June 27, 1984, the GPC-14 committee recommended adopting the following standard numbering system to use for all leafy spurge accessions as they are collected in various locations. This number should accompany the plant material from a given collection site to wherever the material is maintained. The same number should be used in all subsequent laboratory and field research reports. The number consists of the year of collection, followed by a two-letter designation for the state or country of origin, and by a 3-digit number indicating the sequence of the collection of the material. All numbers are to be cleared through a central location to ensure that the same number is not applied to different accessions. The Postal Service designations was to be applied for the two-letter zip designation, and I have been serving as the contact and storage point for the information for the past year. An example of the number system is:

1985 ND 005 = the fifth collection (accession) of root material from North Dakota in 1985. The use of three numbers following the state designation allows for essentially infinite amounts of material for ambitious workers.

Minor problems that have arisen in the implementation of the system are:

1) Several Canadian Provinces are designated by the Postal Service with 4-letter codes.
2) Most foreign countries are designated by one-letter codes.
3) Only a few scientists have responded.
4) Some confusion as to whether such species as *Euphorbia cyperissias* should be included, since some of the genetic studies include this species, and probably others.

The approach I have been taking is as follows:

1) Use a two-letter designation for the Canadian Provinces:

Alberta	- AL	Ontario	- ON
British Columbia	- BC	Quebec	- QU
Manitoba	- MB	Saskatchewan	- SA

Other provinces to be assigned two-letter zip codes later if any collections are made there.

2) Use the one-letter codes used by the Postal Service for other countries.

Austria	A	Hungary	H	Italy I
West Germany	D	Switzerland	CH	(unknown if I is
Romania	R	France	F	ok for Italy)

The above designations for other countries were supplied to me by Dr. Jurgen Schaeffer, Montana State University.

3) I will supply copies of the numbers and collecting information to anyone who requests them, and assist in assigning new numbers when asked.

4) For other known species that are obviously different from E. esula or the North American variants of whatever species designation, the same system will apply, except the number will be followed by a letter to distinguish it; for example:

1982 CH 001 - C is cypress spurge collected in Switzerland in 1982.

I have also accumulated much of the collection data for many of the leafy spurge accessions - those for which numbers have been assigned. A copy of the data sheet will be published in these proceedings. Individuals who wish to use the data sheets for their collections as they are made can photocopy this sheet, or can contact me for copies. Please keep in mind that not all of the information requested on the data sheets has to be filled in. The sheets were designed to accommodate all eventualities. Only the information that is pertinent (or available) should be filled in.

The information on the accessions that is available to me is stored on computer disks and hard copy in my laboratory, and is available to whomever needs it.

In spite of the fact that it may be somewhat inconvenient to fill out these sheets and to clear a numbering system through a second party, my experience has been that it should be well worth that time, because it may save a lot of confusion and time in the long run. So far, I have found it has made it simple to identify specific plants, store information, describe it to colleagues, and write reports and journal papers.

Leafy Spurge Accessions

Please check the appropriate blanks or fill them in.

Accession Number:________________________

Date Collected:____________________________

Collector: Name __________________________

Address ________________________

Phone __________________________

Deposition: Nursery _______

Herbarium _______ Chromosome # __________

Greenhouse _______

Tissue Culture _______ Type ___________

Terminated _______

Collection Site:

Town ______________ County ______________ State ____________

Latitude _____________ Longitude ____________ Section __________

Soil Type ____________ Slope _______________ Aspect ___________

Habitat: Native: Forest______ Shrub ______ Grassland ______

Cropland: Dry_____ Irrigated _____

Grazing _____

Previously Sprayed:

Yes _____ With (chemical) ________________ Unknown _____

No ______

Original McCarty Collection Number: __________ Other Number: __________

Added Habitat Information ____

____

____

Material Distributed to the Following Other Individuals: (give complete addresses and telephone numbers).

____

____

____

____

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The influence of glyphosate on endogenous levels of free IAA and phenolic compounds in leafy spurge

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Introduction

Glyphosate (N-(phosphonomethyl) glycine) is a broad spectrum, foliar applied herbicide which is readily translocated to actively growing tissues in a plant. Its mode of action has been the subject of much research over the past several years, yet the exact means by which the plants are killed remains unclear. Initial research indicated that the shikimic acid pathway, a biochemical pathway unique to plants that is responsible for the biosynthesis of aromatic amino acids, was the site of inhibition (Jaworski 1972). This fact was demonstrated by the ability of the aromatic amino acids, phenylalanine, tyrosine and tryptophan to reverse the herbicidal effects of glyphosate. Subsequent studies have shown that glyphosate treated plant tissue accumulates shikimic acid, an intermediary compound in the pathway, and that glyphosate stops the conversion of shikimic acid to chorismic acid in cell free extracts (Amrhein *et al*. 1980). Recently it was shown that *Escherichia coli* cells could be made resistant to glyphosate by introducing a mutant gene into the bacterium for 3-enolpyruvylshikimic acid-5-phosphate (EPSP) synthase. EPSP synthase is the enzyme responsible for catalyzing the reaction of 5-phosphoshikimic acid with phosphoenolpyruvate to form 3-enolpyruvylshikimic acid-5-phosphate (Comai *et al*. 1983). Additional publications have supported the EPSP synthase inhibition theory, including one which offers evidence that glyphosate binds to the phosphoenolpyruvate binding site of EPSP synthase (Steinrucken *et al*. 1984), and another in which glyphosate resistant carrot cell cultures are shown to have increased EPSP synthase activity (Nafziger *et al*. 1984).

Although there is substantial evidence that EPSP synthase is the major site of glyphosate inhibition there is no proof that this interference directly causes the death of the plant. A deficiency of aromatic amino acids may lead to the disruption of protein synthesis but it has also been reported that after glyphosate treatment the concentration of phenylalanine in either the free state or the metabolic pool was not low enough to limit plant growth (Haderlie *et al*. 1977) Also, a growing body of evidence suggests that IAA levels are closely tied to glyphosate induced injury and this may provide a better explanation for the herbicidal effects. For example, sublethal quantities of glyphosate will produce multiple branches or “witches broom” effects in Bermuda grass (Fernandez *et al*.

1977) and will stimulate the release of lateral buds from apical dominance in soybean and pea seedlings, even though the apical bud is not dead (Lee 1984). Such responses appear similar to release from correlative inhibition in which IAA has traditionally been thought to play a major role. Furthermore, glyphosate also decreases IAA transport in corn and cotton tissue (Baur 1979) and Lee (1980b) found that IAA reversed glyphosate induced inhibition in soybean and tobacco tissue cultures. Likewise glyphosate and 2,4-D (a synthetic auxin), which both inhibit growth when applied separately, act antagonistically when applied to a plant at the same time (O'Sullivan *et al*. 1980). When glyphosate treated callus cultures are supplied with exogenous IAA, neither IAA nor the enzyme IAA oxidase appear to be affected by glyphosate directly, yet there is a decrease in the levels of free IAA while bound IAA and the products of IAA oxidation increase (Lee 1982a,b). These decreases in IAA levels may be due to an observed decrease in the level of phenolic compounds (Lee 1982b), which are known to influence the activity of IAA oxidase (Lee 1980a). It is reasonable to assume that phenolic concentrations are affected by glyphosate since the major precursors of these compounds are phenylalanine and tyrosine. Thus, a postulated site of glyphosate inhibition is linked with decreases in levels of the important phytohormone IAA that could further explain how plant senescence is induced. Since most of the experiments on this topic have been performed either on callus cultures or other isolated plant tissues, this paper presents data on the effects of glyphosate on endogenous levels of IAA and phenolics substances in whole plants.

Materials and methods

General

Leafy spurge was chosen for this experiment for two reasons. First of all, it is a very important weed and represents a potentially real target for glyphosate application. Secondly, leafy spurge possesses a highly unusual anatomy that makes it an interesting organism for the study of IAA, apical dominance, and systemically translocated herbicides. At the base of the stem and on the roots are adventitious buds which are normally held under correlative inhibition but which may, for reasons that are still not completely understood, be released to become new shoots.

The plant material was greenhouse grown leafy spurge, started from seed and used at 4 months of age. Only healthy, single stemmed, actively growing plants were used. The total numbers of plants were divided into 3 treatment groups: glyphosate treated, decapitated, and control. The glyphosate plants were given a foliar dose of 4 lb ae/acre glyphosate (as Roundup) using a field sprayer simulator. This dosage had been previously found to be lethal to similar plants. The decapitated group had the apical region (including the youngest leaves) removed at time zero. This group served as a control to simulate removal of an endogenous source of 1AA. The third group was left intact as a control. Plants were harvested at 0.5, 1, 3, 5 and 7 days after treatment. The soil was washed from the roots, they were lyophilized, and then divided into three parts: shoots (stems and leaves), hypocotylar region (containing most of the adventitious buds), and roots. The tissues were ground and passed through a fine mesh before chemical analysis.

Free IAA analysis

The plant tissue was extracted in 80% methanol at 4 C for a total of six hours, centrifuged, and the extract was evaporated to the aqueous phase under reduced pressure. A known amount of (2-^{14}C)IAA as an internal standard was added to the residue. The sample was then partitioned against ether using the method of Knegt and Bruinsma (1973) in which the IAA in a basic solution was shaken against ether. At a basic pH the IAA stayed in the aqueous phase and hydrophobic contaminants were removed. By changing the solution to an acidic pH the IAA became associated with the ether phase allowing for the removal of polar contaminants. The final ether phase was made basic and reduced to less than 0.5 ml volume. Additional purification was by HPLC using a Nucleosil C18 column and reversed phase chromatography with a 30-minute linear gradient from 0.lN acetic acid to 0.1N acetic acid in 50% ethanol. A U.V. detector set at 280 nm was used to monitor the runs and the IAA peak was collected according to the retention time of authentic IAA standards. The final analysis. was done by HPLC using an Adsorbophere HS C18 column and ion pair chromatography. The mobile phase consisted of 30% MeOH with 0.01 M $NaP0_4$ and 0.005 M tetrabutylammonium phosphate and was delivered isocratically. Identification and quantification was done using a sequential arrangement of fluorescence (excitation=254 nm, emission=340 nm) and electrochemical (potential= +0.8 volts) detectors in sequence. These are both very selective and sensitive detectors, such that IAA was the only compound to produce a simultaneous response. The IAA peak was collected and the internal standard recovery was measured by liquid scintillation spectrophotometer to determine the losses of IAA during the purification procedure. The identity of IAA was confirmed by methylation and mass spectrometer analysis of the putative IAA-containing fraction.

Total phenolics assay

The assay for total phenolic compounds was modified after that of Singleton *et al*. (1965). Phenolic compounds were extracted from plant tissue in boiling 80% methanol. After cooling and centrifugation, an aliquot of this solution was used in a reaction with the Folin-Ciocalteu reagent, forming a colored product that was spectrophotometrically quantified at 765 nm. The standard curve was prepared from an equimolar mixture of caffeic acid, chlorogenic acid, p-coumaric acid, and quercitin.

Results and discussion

Free IAA

The application of a lethal dose of glyphosate to leafy spurge plants caused a significant decrease in IAA concentration in all plant organs relative to the control. In shoots (fig. 1A) the glyphosate treated plants showed a 22% decrease in IAA concentration after only 12 hours indicating that glyphosate has a relatively rapid effect on the metabolism of IAA. Interestingly, the IAA concentration rises to near normal levels on the third day before dropping again to 33% less than the control on day 7. The decapitated plants showed initially normal levels of IAA but dropped on days 3 and 5 before rising substantially on day 7. This could be explained by traditional apical dominance theory, which predicts that levels of IAA would decrease until lateral bud inhibition was removed whereupon the rapid growth of lateral buds would produce increased IAA concentrations. It should be pointed out that at 12 and 24 hours the IAA concentration in the glyphosate treated shoots are lower than that of the decapitated plants, implying that glyphosate may not only remove the source of IAA, but may cause an increase in IAA conjugation and/or degradation as shown in tissue culture (Lee 1982b).

The hypocotylar region shows higher variation in IAA concentrations (fig.1B), which may be due to the presence of adventitious buds in different states of metabolic activity, which commonly develop in this region of the plant axis. No noticeable change in the length of buds occurred after treatment. The glyphosate treated plants show lowered IAA concentrations with the exceptions of days 1 and 7. The decapitated plants display a steady increase until day 5, followed by a decrease. Again this could be explained as increasing IAA synthesis by the rapid growth of many buds newly released from the inhibition of apical dominance until one or two new shoots assert dominance over the others and the IAA levels return to normal.

Glyphosate treatment decreases the IAA concentrations in roots (fig. 1C) by 35% and 31% on days 3 and 5 respectively. However, this delayed response may represent the lag time between the time of herbicide application and when it reaches the roots. A (^{14}C)glyphosate study in leafy spurge demonstrated that two days were required for significant amounts of glyphosate to reach the root and maximum accumulation was not achieved until seven or more days (Gottrup *et al.* 1976). Thus the glyphposate induced decrease was not apparent until the third day. Decapitated plants display an opposite trend, rising steadily for the first three days rather than decreasing. It is possible that adventitious buds on the roots are being released from dormancy, becoming sites of IAA synthesis, and thus increasing the IAA concentration in the roots. Interestingly, decapitation seems to result in slightly elevated IAA concentrations by day 7 in all plant parts.

Finally, it is worthwhile to compare the relative concentrations of IAA among the plant parts under study. The mean values of the controls for the hypocotylar regions, shoots, and roots contained 195.3, 131.4, and 93.4 ng/g dry wt. IAA respectively. Of these, the roots showed the least amount of variation, followed by shoots and finally hypocotylar regions which showed the greatest fluctuations. We assume that this difference is related to the number and developmental stage of adventitious buds. A bud held under inhibition does not contain as much IAA as an actively growing bud (Hillman *et al.* 1977), yet they may appear similar under routine examination. Thus it appears that in young leafy spurge plants the adventitious buds of the hypocotylar region may contain considerably more IAA and so may be more likely to start growing than buds on either the roots or shoots.

Phenolic compounds

The application of glyphosate to intact leafy spurge plants produced a significant decrease in phenolic compound levels only in the hypocotylar region of the plant (fig. 1E). In roots (fig. 1F) there was no difference between the groups at any time, while in shoots (fig. 1D) at day 5 the glyphosate treated tissue contained significantly more phenolics relative to the control but by day 7 the level had returned to normal. Decapitation resulted in increased phenolic levels in the shoots only. No other significant differences were found in the analysis of phenolic compounds.

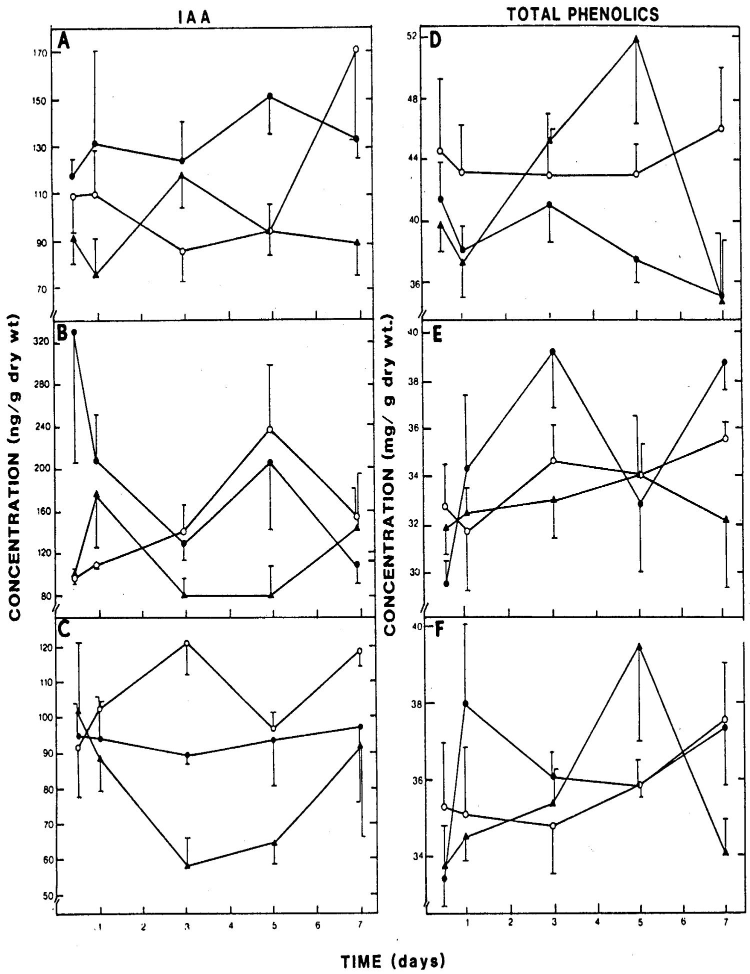

Figure 1. A) Effect of glyphosate and decapitation on free IAA levels in leafy spurge shoots; B) effect of glyphosate and decapitation on free IAA levels in leafy spurge hypocotylar regions; C) effect of glyphosate and decapitation on free IAA levels in leafy spurge roots; D) effect of glyphosate and decapitation on levels of total phenolics in leafy spurge shoots; E) effect of glyphosate and decapitation on levels of total phenolics in leafy spurge hypocotylar regions; F) effect of glyphosate and decapitation on levels of total plenolics in leafy spurge roots. ▲ -glyphosate treated, ○-decapitated, ●-control.

Conclusions

A lethal dose of glyphosate applied to intact, single stemmed leafy spurge plants produced a significant decrease in IAA concentrations in shoots, hypocotylar regions, and roots. Since this decrease did not resemble decapitation of the plants it serves as additional evidence that glyphosate in some way alters IAA metabolism. However, analysis of phenolic compounds did not entirely support the previous reports of lowered phenolic compounds in glyphosate treated tissue. Only the hypocotylar region showed a significantly lower concentration of phenolic compounds. In summary, this experiment substantiates the hypothesis that glyphosate causes a reduction in endogenous levels of free IAA in whole plants but only partially supports a hypothesized decrease in total phenolics.

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The physiology of leafy spurge root bud dormancy

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Anyone who has been around leafy spurge very much knows the vegetative root buds are key to the persistence of this weed. The tremendous root system of leafy spurge stores enough carbohydrate for several years, and anytime the top growth is disturbed. The adventitious shoot buds can produce new photosynthetic growth. Our research has focused on factors which control the growth of these root buds.

We have worked with plants that have extensive root systems, so that we could study the root buds along the entire length of the root system. Uniform plant material was produced by taking root cuttings of a single plant. Plants were grown in containers for several months and then these plants were transferred to large PCV pipe 4" diameter and 39" long. Plants range in age from 1 to 2 years, so we feel this is fairly representative of a field-type perennial plant; Leafy spurge does extremely well in this system.

Using plants grown in the system I have just described, a wide variety of experiments have been performed, all aimed at developing an understanding of root bud dormancy. Initial work examined the relationship between growth and 1) bud size, 2) distance of the bud from the crown, and 3) diameter of the root on which the bud is located. We also were interested in the effects of chilling temperatures on the growth response of leafy spurge root buds since chilling temperatures have been shown to affect the growth of buds in many types of plants.

Controlling bud growth with exogenous auxin applications and ethylene inhibitors has also been examined.

On the whole plant basis, we have determined the effects of TIBA, which restricts the polar movement of IAA in the plant. The flow of auxin from the top part of the plant to the lower part can be restricted using this compound. We have also worked with materials called cytokinins, which stimulate cell division and are currently engaged in measuring endogenous IAA levels in root buds.

By looking at the growth response of the bud in relationship to the initial size, the distance from the crown, and the root diameter. We hoped to determine how these parameters related to the potential for new shoot production. The potential of each bud on the root system to produce new shoots appears to be about equal. This means that any bud remaining alive has the potential to produce some new growth.

Now, let's examine the effects of chilling temperatures on root bud activity. The only time we found a positive response from chilling temperatures was after flowering, during that period we call summer dormancy. Leafy spurge will often lose its leaves after seed set and be in a dormant state until fall rains come. Regrowth from axillary buds marks the end of summer dormancy.

We found that root buds from plants which were setting seed grew very little. By placing intact plants in a cold room at 4°C for 8 days, a dramatic increase in root bud activity was produced. This indicated that the buds of leafy spurge respond to chilling temperatures and that fall or summer dormancy may be alleviated by over-wintering. This may partially explain the geographic distribution of spurge.

For our work with exogenous plant hormones, we devised a simple system where the hormone is placed in buffered solution in a small plastic vial, the open end covered with parafilm, and the end of a 2-cm root piece containing one root bud is pushed a short distance through the parafilm to contact the solution. A series of experiments were conducted in which we looked at the effect of varying levels of exogenous IAA and NAA, a synthetic auxin, on root bud growth. We were not able to stimulate growth, but we were able to inhibit the growth of buds by high IAA levels. We repeated the same experiment with NAA (napthalene acetic acid) and found it to be 100 times more effective in reducing root bud growth.

Working with exogenous plant growth regulators provides valuable information about the plants' physiology but it can lead to erroneous conclusion. That is why measuring endogenous IAA levels in the root buds is very important. IAA behaves as a weak acid, a property which is often used to separate it from other compounds in the plant. At pH 9.0, IAA is water soluble while at pH 2.7, it is soluble in organic solvents. We use this property of the molecule to do our separations and HPLC work.

Reverse phase high performance liquid chromatography (RPLC) was used in combination with fluorescence detection to measure endogenous IAA levels. The limit of sensitivity is approximately 1 ng per injection.

Approximately 100 milligrams of bud tissue is required to determine free IAA levels. A dormant bud from a plant which is growing vegetatively, has a free IAA level of 650-nanograms/gram fresh weight. In buds from flowering plants, a somewhat higher level was measured. In comparison, the roots themselves have about 20-nanograms/gm fresh weight. There is about 50 times more IAA concentrated in the root buds.

In the process of measuring IAA levels in spurge root buds, we also found an unusual auxin compound present indole proponic acid (IPA). It was first reported in 1983 and has been reported in only three plant species to date. IPA is not a strong promoter of cell elongation but is more potent than IAA at producing lateral root formation.

I would like to summarize by listing some of the basic conclusions from the research we have conducted at Montana State University on the physiology of root bud dormancy. (1) All the buds have a tremendous potential for growth. (2) Chilling temperatures appear to be critical during certain life stages of the plant. (3) Growth of the root buds can be inhibited with high exogenous auxin levels. (4) No response from ethylene inhibitors indicated that ethylene was not involved in root bud inhibition. (5) A small stimulation of growth was produced using TIBA but not cytokinins. (6) Dormant root buds were found to have high levels of free IAA. (7) A unique auxin compound called Indol-3-Proponic acid was identified in the root buds of leafy spurge.

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Triterpenoids in latex: Their synthesis and possible role in *Euphorbia*

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Introduction

The topic that I want to discuss today is related to the latex of the *Euphorbia* plant, including *Euphorbia esula* L., the spurge. In our last meeting I emphasized that the latex is produced in a specialized cell termed the laticifer cell. This cell is initiated in the embryo and then progressively grows throughout the plant as a single-cell type to form a long coenocytic cell. It is the longest of biological cell types (1). The unusual feature about this cell in the genus *Euphorbia* and some related genera is that it undergoes a specialized synthetic activity for production of various toxic triterpenoids, the accumulation of rubber, and also the accumulation of starch within laticifer plastids.

Last year I emphasized that the triterpenoids from the latex of 10 different populations analyzed by gas liquid chromotography separated these populations into three distinctive groups based on the profile of their triterpenoids (2). Specific profiles of triterpenoids have been recorded for individual taxa examined in other studies in my laboratory (3). From these results I have postulated that the triterpenoid profile represents a fingerprint for a taxon (4). A question posed by the occurrence of stable and distinctive profiles within a given population or taxon relates to where these triterpenoids are produced in the plant. We undertook studies to examine the sites of synthesis of these compounds in latex fractions using labeled acetate and malvalonate of the squalene pathway (5). The purpose of this study is to interrelate triterpenoid synthesis with organellar components of the cell and project a hypothesis of the function of the laticifer and its unusual contents.

Results and discussion

Latex, upon fractionation, is separated into three distinctive fractions. An upper fraction, which is the so-called triterpene particle fraction including rubber content, a large, clear serum middle fraction, and a small bottom fraction which includes the plastids and membranes of tubular form. Similar fractions are obtained from latex of all examined *Euphorbia*. This material is very difficult to handle because as soon as you begin manipulating the rubber fraction of exuded latex, it begins to coagulate. This phenomenon can be minimized by collecting the latex exudate directly into phosphate buffer, passing it through a sephadex column, and eluting the particles from the column with water. With this procedure one can isolate the triterpene-rubber particles as specific particles (5).

Each triterpene particle from the upper fraction, when examined by transmission electron microscopy, consists of an electron dense body surrounded by a membrane. These particles are capable of incorporating both mevalonate and acetate to synthesize triterpenes. The serum fraction contains no morphological details when examined by electron microscopy. It does not incorporate labeled acetate or mevalonate (5).

In the bottom fraction, we find starch grain-containing plastids as well as abundant tubular membranes associated with the plastids. This fraction was most active in triterpenoid synthesis and incorporated both acetate and mevalonate for this activity (5). Structural details of the membranes show small electron dense masses between the membranes. These masses resemble closely the larger rubber particles of the upper triterpene-containing fraction; and it appears that these small bodies, which typically appear as spherical bodies along these membranes, may be pinched off to form membrane-bound particles in the cytoplasm. In this way, the plastic membrane fraction is associated with the synthesis of triterpenoids and the formation of rubber particles. These particles upon release from the membranes contributes to the upper triterpenoid-rubber fraction. It is unclear, at present, how these particles become enlarged after their release from the tubular membranes.

The lipophilic rubber particles physically represent the prominent component of the upper fraction. Since the triterpenoids accumulate to high concentrations, as high as 40% dry weight of latex, the rubber particles compartmentalize these compounds and remove them from the metabolic stream. Thus, the rubber particles function to store these generally toxic compounds. This interpretation is supported from studies on other latex bearing plants where, if triterpenoids are absent, the rubber is absent. Thus, the evolution of rubber may correlate with the evolution of the triterpenoid pathway in the laticifer.

The function of the laticifer contents is interpreted to relate to protection against predation. Phytophagous insects and larger animals foraging upon the plant would receive amounts of latex exudate containing high concentrations of triterpenoids. The qualitative and qualitative differences for triterpenoids among different taxa is interpreted to be a result of coevolutionary pressures between the plants and on obligate insects. An obvious example would be reflected by a qualitative alteration of the triterpenoid composition representing speciation (chemotype alteration) and resulting in a plant now unpalatable to the obligate predator. However, insect evolution can be expected to result in a form able to forage upon the evolved species with its altered triterpenoid composition. Repetition of this coevolutionary scenario provides an explanation of the origins of *Euphorbia* species with diverse triterpenoid components and the obligate or selective feeding habits of insects associated with the genus.

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Cytogenetics of leafy spurge

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A greenhouse collection of 145 clones comprising 126 known accessions and 8 unknown or mislabeled accessions of the weedy *Euphorbia* species collected in Montana, Washington, Oregon, Idaho, Wyoming, Nevada, Colorado, North Dakota, Nebraska, Minnesota, Iowa, Michigan, Maryland, New Jersey, Pennsylvania, British Colombia, Alberta, Saskatchewan, Ontario, Austria, Hungary, Switzerland, Yugoslavia, and Italy has been established at Bozeman, Montana for cytogenetic analysis. The material was provided by weed supervisors, University personnel, and federal laboratories. Particular mention should be made of the generous contributions of the Plant Disease Laboratory at Frederick, Maryland; North Dakota State University at Fargo, North Dakota; the USDA Metabolism and Radiation Research Laboratory at Fargo; the Alberta Environmental Center at Vegreville, Alberta; and the Biosystematics Research Institute at Ottawa, Ontario.

A survey of the literature shows chromosome numbers for *E. esula* of 2n=16, 60, and 64; for *E. virgata* 2n=56; and for *E. cyparissias* 2n=20, 36, and 40. We found chromosome numbers of 2n=56 and 60 for *E. esula*, 2n=40 to ±80 for. *E. pseudovirgata*, and 2n=36, 40, and 42 for *E. cyparissias*. Our study of 614 cells in 94 plants revealed a high degree of somatic instability, mixoploidy, or mosaicism considered by some to be an indication for interspecific hybridization. The nature of such somatic instability was contributed by Nielsen and Nath (1961) to possible unbalanced nucleoprotein systems that resulted from the combination of distantly related gametes in the formation of such interspecific hybrids.

A map of accessions collected from Oregon, Washington, Montana, Wyoming, North Dakota, Alberta, and Saskatchewan shows that prevailing 2n chromosome numbers range from 52 in Flathead Co., Montana, to 64 in Teton Co. , Montana. Nearly all plants in this area exhibited some degree of somatic instability. This confirms earlier hypotheses (Croizat, 1945; Radcliffe-Smith, 1981) that this material originates from introgressive hybridization between two or more species, one of which is probably *E. esula*. This is also reflected in the composite idiograms of *E. esula* (2n=60) and *E. pseudovirgata* (2n=60), which show a resemblance of chromosome morphology in these species. Our morphological studies of leaf characteristics indicated that genetic material of *E. esula*, *E. virgata*, *E. cyparissias*, and *E. uralensis* can be suspected in this complex species group.

A map of prevailing chromosome numbers arranged according to states and provinces shows the greatest range in Montana (2n=52-64).

Five major types of nucleolus organizer chromosomes (I-V) were identified in this study. Confirmation of their existence was given through the study of the nucleoli formed by them. Preliminary counts showed from 1 to 6 nucleoli per cell with 33% having 5 nucleoli. Polymorphism was reflected in the number of nucleolus organizer chromosomes per plant. *E. pseudovirgata* showed all 5 nucleolus organizer chromosome types with an average of 3.3 pairs per cell, *E. esula* showed types I, II, IV, and V, with an average of 3.8 per cell, and *E. cyparissias* had types II and III with 2 pairs per cell.

Segmental allopolyploidy is suggested at the tetraploid and hexaploid chromosome levels as well, with genome formulas AABBCC for *E. pseudovirgata* (2n=60) and *E. esula* (2n=60), and AABB for *E. cyparissias*, with A, B, and C chromosomes resembling each other closely morphologically.

Meiosis in *E. pseudovirgata* was normal with only about 40% of the cells showing one univalent.

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Release of *Oberea erythrocephala* in Montana

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Leafy spurge is a serious pest plant of the United States and Canadian rangelands. *Oberea erythrocephala*, a stem and shoot mining cerambycid beetle of leafy spurge, was introduced into Oregon, Montana, and Wyoming between 1980 and 1984. Although not recovered in Oregon and Wyoming, it did become established at three of four release sites in Montana (Bozeman, Columbus, Fairview), and has just been released at a fifth (Reed Point). When it has increased to sufficient numbers, this agent will assist other bioweed agents in suppressing the populations of leafy spurge.

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Status of research on European plant pathogens of leafy spurge

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Sherry Turner's pathogens

In 1982 Sherry Turner traveled to Europe (via grant funds from Dr. Peter Fay, Montana State University) and collected plant pathogens of cypress and leafy spurges from Hungary, Austria, and Switzerland. Eighteen isolates of rust were obtained from eighty-two collection sites from leafy spurges identified as *E. virgata* Waldst. & Kit, *E. esula* L. and cypress spurge, *Euphorbia cyparissias* L. No root invading pathogens were observed. Plant pathogen and host plant material were brought back to the USDA Plant Disease Research Laboratory (PDRL), Frederick, Maryland, for virulence, host range, and host specificity testing. Rust isolates were stored in liquid nitrogen until plants were available to inoculate. The various isolates established in the containment greenhouse were tested on numerous collections of leafy and cypress spurge from Europe and North America.

Turner found that isolates were most aggressive toward the original European plant collections. She observed limited infections from two isolates of *Melampsora* sp. on six North American ecotypes of leafy spurge. Two other isolates of *Melampsora* sp. each infected two cypress spurge collections. Another rust species, *Uromyces scutellatus*, was found to infect cypress spurge but proved extremely difficult to work with. Since research on *U. scutellatus* had already been initiated by Dr. Genevieve Defago, a plant pathologist at the Institut fur Phytomedizin in Zurich, Switzerland, Bruckart and Turner agreed that the Swiss scientists should concentrate on it and the PDRL scientists on the isolates of *Melampsora*.

At this point in the screening, research funding ran out. Dr. Bruckart and I agreed the research was important enough to merit continuation. Funding was acquired from CSRS and a cooperative agreement was developed between Montana State University and PDRL to finish the screening of Sherry Turner's pathogens. If some safe and promising pathogens were identified at PDRL, plans were made to eventually field test them in Montana and the western region. Ms. Turner left PDRL and Eileen Sutker was hired to finish the screening work at PDRL. Ms. Sutker worked on techniques for improved greenhouse propagation of leafy spurge, methods of inoculation, and the effects of temperature on urediniospore germination. Only one rust isolate was very aggressive on leaves and stems of cypress spurge. Unfortunately this *Melampsora* species infected only one collection of cypress spurge from Austria and had little or no effect on leafy spurges from North America or Europe. In view of this, Dr. Bruckart and I agreed that the *Melampsora* isolates collected by Turner were not suitable candidates for biocontrol of leafy spurge and that funds should be redirected towards the collection of new pathogens of leafy spurge from Europe.

Dr. Defago, with the Institut fur Phytomedizin in Zurich, Switzerland, agreed to make arrangements for scientists from her lab and cooperators from other countries to collect leafy spurge pathogens during the spring and summer of 1985 and 1986. Pathogen surveys/collections will be made initially in Czechoslovakia, France, Germany, Italy, and Switzerland.

Screening research - *Uromyces scutellatus*

In a cooperative effort, funded by the USDA, among Montana State University, the USDA-PDRL, and Institut fur Phytomedizin (IFP) a promising rust, *Uromyces scutellatus*, is being screened by Dr. Defago at the IFP in Zurich, Switzerland. Dr. Defago is currently conducting host range and specificity tests of *U. scutellatus* on cypress and leafy spurges.

Uromyces scutellatus is a systemic rust fungus that attacks the leaves and stems of cypress and leafy spurges causing premature shoot death. Infected stems fail to flower and produce seeds. Symptom expression occurs two years following inoculation. Dr. Defago is studying ways to improve infection of plants in the laboratory and is following the impact of *U. scutellatus*, in natural and artificially inoculated stands of cypress spurge in the field. Field observations have shown that the rust causes a dramatic decline in the number of cypress spurge stems per unit area following the two-year incubation period.

Defago also is testing virulence of the rust fungus on seedling and root stock material sent from Montana in 1984. If *U. scutellatus* is aggressive toward collections of leafy spurge from North America, then the screening research hopefully will be accelerated.

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Continued studies of plant pathogenic fungi for biocontrol of leafy spurge in North Dakota

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During 1984-1985 we have further studied pathogenic fungi, with potential for biocontrol of leafy spurge, *Euphorbia esula*.

Sclerotium rolfsii isolates have been obtained from other parts of the country. Inoculum is being prepared for greenhouse testing in the winter of 1985.

During the summer of 1984, field inoculations with greenhouse effective *Alternaria tenussina* f. sp. *euphorbiae* were made onto leafy spurge. At the three field sites (two North Dakota and one Montana) only a few inoculated plants were infected, and leafy spurge growth as measured by dry weight was not reduced significantly, compared to checks. Moisture appeared to be inadequate for severe disease.

To overcome the problem of applying alternaria during periods of inadequate moisture an approach using pellets have been initiated. Sodium alginate-pellets (1) containing alternaria have been prepared in our laboratory. In the greenhouse and field this winter and next summer the pellets will be scattered among the spurge. It is hoped that the fungus will survive in the pellets and during periods of adequate moisture spores that will infect spurge will be produced from the mycelium in the pellets.

Melampsora rust spp. occur on *Euphorbia* spp. and are highly specific for their hosts. This combined with their urediospore on *Euphorbia* spp. makes them good candidates for biocontrol of leafy spurge. *Melampsora euphorbiae* was collected at Victoria, B.C. by Dr. Littlefield in August, 1984 and sent to the Plant Disease Research Laboratory (PDRL) at Frederic, Maryland. *Uromyces euphorbiae* was collected by Dr. Littlefield on a collecting trip to Eastern Europe in the spring of 1984, and that rust was also sent to PDRL. Evaluation of these rusts for host range, prior to release to us, is in progress. As recommended by Dr. Littlefield, Dr. Hosford plans to collect physiological races of *Melampsora* spp. on leafy spurge in Oregon and Washington in the fall of 1985 for evaluation at Fargo, North Dakota.

The rust, *Uromyces striatus*, was found on leafy spurge in the southeast corner of North Dakota in 1982 and diseased plants were labeled and plotted. In 1983, 1984, and 1985 diseased plants died and disease spread slowly to adjoining spurge plants presumably through systemic mycelium in their roots. We considered *U. striatus* to be a poor candidate for biocontrol of leafy spurge in 1984. This was because the uredial stage occurs on alfalfa, an economic crop in North Dakota, and the slow spread of the rust on leafy spurge. However, alfalfa rust is a minor problem in the northern states, and this pathogen appears to attack the roots that regenerate spurge when its top is killed by herbicides. Also, in 1985 the area of infected spurge dramatically increased from the initial plots to cover an area of approximately three acres, indicating spread by airborne spores. We found in the spring of 1985 for the first time the rust on alfalfa plants close to diseased leafy spurge plots. The continued and accelerated spread of this rust without the need for repeated application of mycoherbicide and its low incidence on alfalfa has renewed our interest in this fungus. We will continue following its spread in the field. Studies are underway in the greenhouse to increase the rust on two susceptible alfalfa cultivars and to infect leafy spurge from the rusted alfalfa. Histological work is underway to stain systemic mycelium in horizontal roots joining diseases aerial plant parts, so that fungal spread through the roots can be examined in preparation for attempts to accelerate the spread of disease in leafy spurge.

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Biological control of leafy spurge: Stress factors, selection and evaluation of natural enemies

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Biological weed control programs are being analyzed to determine new techniques to select and evaluate agents. Few studies on the effect of the agents on the weed prior to release have been made, and in this report, several aspects of physiological and stress factors are discussed with reference to several agents used against leafy spurge (*Euphorbia esula*).

In Saskatchewan, several insects on leafy spurge are under investigation. Canadian laboratories have screened or are screening 13 spurge insects. Two flea beetles, *Aphthona flava* and *A. cyparissias* have completed one year in the field and survival for a second season remains to be confirmed. *Oberea erythrocephala*, which survived for several years, seems to have died out. The spurge hawkmoth, *Hyles euphorbiae*, established on leafy spurge in Montana and on cypress spurge in Ontario, and *Lobesia euphorbiana*, a leaf tying moth were released last year in Saskatchewan and evaluation of survival is in progress. Another flea beetle, *Aphthona czwalinae* was released this spring. In addition, there are several insects in quarantine at various stages of testing: *Minoa murinata* the spurge looper and two aphids, *Acrythosiphon cyparissae* and *Aphis esulae* in the Regina laboratory and other insects in other regions: *Pegomya* sp., the spurge root gall fly and *Aphthona nigriscutis*. *Chamaespecia empiformis* and *C. tenthredinisformis* (clear-winged moths) have been released, but did not survive on North American leafy spurge. A survey of endemic pathogens was made, but no promising prospects were found.

Degree of damage

It seems simplistic to state that the greater the damage to the plant as a result of agent feeding, the more the plant is adversely affected. The relationship between defoliation and plant physiology and growth has been examined by studies on *Minoa murinata* and by defoliation simulation. Ecological and crop defoliation studies have shown that most plants have a threshold level of damage, below which the plant is not adversely affected. Compensatory growth responses enable the plant to overcome the loss of tissue (McNaughton 1983). The threshold concept is important for the biological control of a plant like leafy spurge, which is likely to require several agents to achieve control (Harris in press). If the amount of damage needed to disadvantage the plant is known, then the amount of damage caused by each agent can be related to the threshold value and progress toward the threshold can be measured. Preliminary results indicate that for perennial weeds, such as Canada thistle and leafy spurge, greater than 75% of annual production will have to be removed. Observations in 1984 with a cage release indicated that after a substantial defoliation by the spurge hawkmoth, regrowth of side shoots occurred and this year's growth is slightly delayed. There is also a possibility that insects have been released that benefit the plant. Preliminary root removal studies of leafy spurge at various ages indicate that certain levels of root removal stimulate ramet (shoots originating from the roots) production. Whether this is detrimental to the plant remains to be determined. Leafy spurge, under moist conditions, can withstand a large proportion of root removal without apparent changes in growth rate or weight, but this may differ under dry conditions. The effect of the *Aphthona* spp., whose larvae feed on the root, still has to be evaluated.

Time factors

Classical biocontrol is a long term commitment and an immediate and noticeable decline of the weed population does not occur. It is not known how many years of complete defoliation would be required to reduce the population.

Within the year, time is also an important factor. Current research on perennial weeds indicates that the longer feeding or other stress occurs, the more often it is repeated and for some forms of stress, such as gall causers, the earlier it occurs in the year the more detrimental it is to the plant (Forsyth and Watson in press). Leafy spurge emerges and completes its life cycle early; seed production occurs in mid to late July. It may be difficult to locate an agent that attacks the plant early.

One of the problems with classical biocontrol is that it is not possible to predict precisely and reliably the behavior of an agent in a new environment. There are no proven methods to determine whether an insect will feed or a pathogen will be virulent, how often attack will occur or whether or how often the agent will reproduce, as new weather conditions, ecotype of the weed et cetera are different from those of the area of origin of the agent. An example of failures attributable to these differences include the *Chamaespecia* spp., which cannot survive on Canadian leafy spurge. A new adult generation of *Lobesia euphorbiana* emerged just before frost last fall, and it has not yet been determined if this behavior has resulted in the demise of the colony.

Type of damage

For many years the type of damage was considered important; that there was a hierarchy of attack loci. This has not held true; several different feeding strategies have proven effective and effectiveness is a function of an interplay between amount and timing of damage and physiological state of the weed. For the more troublesome perennial weeds, which seem to need a large number of agents, perhaps the best strategy is to attack the plant in as many loci as possible, with the hope that with a combination, control will be achieved.

Biocontrol is done by government agencies as a public service. In Australia, public concern and support for biocontrol is registered by public hearings and thereby the government has the necessary feedback to evaluate the need, progress and problems of each project. Such a system could be useful in North America, but meanwhile action for biocontrol must be precipitated by the client group making known to the government that they are interested in biocontrol of spurge. Without this, progress is likely to be slow, since there are other public groups suggesting that spurge is valuable as a hydrocarbon, drug or sugar source or that the agents may endanger rare native spurges.

It is becoming increasingly obvious that in order to reach the threshold level of damage of leafy spurge and to overcome the high variability of the leafy spurge plant in North America, more and new agents with increasingly broader host ranges will have to be selected. In the highly variable hybrid, *Lantana camara*, insects defoliate some bushes, but not adjacent ones. An attempt to use agents with slightly broader host ranges has been tested recently. *Minoa murinata*, the spurge looper, has been approved for release by Canadian authorities, but approval has been withheld by the U.S. due to possible "harassment" of endangered or rare native spurges. Most evidence indicates that rarity or extinction occur because of a shortage of habitats resulting in part from displacement by weedy species, such as leafy spurge and chemical control measures against the weed, rather by than feeding of specialized insects.

In conclusion, biocontrol could be aided by improving the selection process to include more studies on the effect of the agent on the weed to be able to predict which and avoid agents that; (a) cause insufficient damage, (b) are poorly synchronized with the most susceptible plant stage and (c) will not survive in the new region. Also action needs to be taken to increase public support and to avoid conflicts of interest over possible "endangered species".

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Two new insects (*Dasineura capitigena* and *Aphthona flava*) for leafy spurge control in United States[1]

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During the past year we have completed the host plant specificity testing, obtained governmental clearances for importation, and have begun releases of two new insects for the biological control of leafy spurge (*Euphorbia esula* complex).

Aphthona flava (Coleoptera: Chrysomelidae), a flea beetle, is one of the many *Aphthona* species which attack *Euphorbia* species in Europe. Like the other *Aphthona* species, the adults of *A. flava* feed on the leaves of their host plants, while the larvae feed on the root hairs and within the roots (Maw 1981). This insect was first evaluated as a biological control candidate for leafy spurge by G. Sommer and E. Maw at the Commonwealth Institute of Biological Control in Delemont, Switzerland[1]. This research demonstrated that the beetle was specific to species belonging to the genus *Euphorbia* (Sommer and Maw 1982) and provided the basis on which the insect was released in Canada and imported to our laboratory in Albany, California for additional testing. Additional tests were required due to the large number of non-target testing. Additional tests were required due to the large number of non-target native *Euphorbia* species in the United States, which could become hosts of the biological control agents. Canada has only eight native *Euphorbia* species, none of which are rare, whereas the United States has 113 species of *Euphorbia* and *Chamaesyce* species (USDA 1982) including 9 rare and endangered species (USDI, FWS 1980, 1983). Selective testing enables us to predict what the host plant range, within the *Euphorbia* and *Chamaesyce* groups, of an insect could become if it was released into the United States. Our goal is to select among the genus level specialists, insect species which will attack the various forms of leafy spurge, but not most native species (Pemberton, in press). This approach appears to be quite possible, since many of the insects tested have the desired level of host plant specificity.

Aphthona flava was tested against 12 native *Euphorbia* species selected to represent the various subgenera occurring in North America. Native test plants also included species which are sympatric with leafy spurge, widespread species which could potentially carry the biological control agents around the country and onto rare species (i.e., bridging

[1] This work was funded by the Canadian Department of Agriculture and to a lesser degree by the United States Department of Agriculture.

species), species which have ornamental or weedy characteristics, and lastly two species which are rare and closely related to leafy spurge.

Of these, *A. flava* was only able to complete its life cycle on some subgenus Esula species (4 of the 6 tested). The Esula subgenus contains 21 species of which 11 are perennials, a condition thought to be necessary in a host plant of this univoltine root-feeder. These 11 perennial species include two rare species (*Euphorbia purpurea* and *E. telephiodes*) which were tested, but also failed to support the full life cycle of *A. flava*. This host specificity testing allows the prediction that not more than 9 subgenus Esula species (countrywide) may become host plants for this flea beetle (Pemberton and Johnson, 1984). This level of risks was acceptable to the Federal Working Group on Biological Control of Weeds, which approved the beetle's release in the United States.

Releases of *A. flava* began in mid-July 1985 and continued through August in and near Bozeman, Montana by Norm Rees (USDA-ARS, Bozeman) and myself (RWP) and in Glacier National Park by Maura Longden and Dave Lange (National Park Service, Glacier). These *A. flava* were collected in northern Italy from *Euphorbia esula* by P. Pecora and then held in the USDA Albany quarantine to observe normal feeding, mating, and oviposition on leafy spurge before being released. Since *A. flava* has successfully overwintered at Canadian release sites in Saskatchewan and Alberta (McClay and Harris 1984), we are optimistic that it will establish in the United States. We hope that *A. flava* will, through its root-feeding, reduce the ability of leafy spurge to absorb water, thereby inducing stress and reduced vigor. *A. flava* is the first of several *Aphthona* species under study by Albany to be cleared and released in the United States. A second species, *A. cyparissiae*, may be ready for use in 1986.

Dasineura capitigena (Bremi) (*Bayeria capitigena*) is a gall midge (Diptera: Cecidomyidae) which attacks the meristematic shoot tips of leafy spurge. It is widely distributed in Europe where it uses eight species of *Euphorbia* as host plants. This insect is multivoltine and is thought to have as many as five generations per season in northern Italy (Pecora 1983). Shoots which are galled usually fail to produce flowers and seed.

D. capitigena was studied as a biological control candidate and demonstrated to be host specific to the genus *Euphorbia* by Pasquale Pecora of the USDA's Rome Biological Control of Weeds Laboratory (Pecora 1983). This research allowed us to bring the midge into our quarantine laboratory for testing against 12 representative native *Euphorbia* species. Its predicted host range was found to be similar to that of *Aphthona flava*, in that it is restricted to subgenus Esula species. It also failed to use the rare subgenus Esula species *E. telephiodes* and *E. purpurea*. Unlike *A. flava*, it can use (in laboratory testing) annual species of the subgenus Esula. From our tests we predict that should *D. capitigena* become established throughout the United States (an unlikely event) it could potentially utilize 19 or fewer subgenus Esula *Euphorbia* species (Pemberton and Johnson 1984b). This level of risks was acceptable to the Federal Working Group of Biological Control who approved release.

The first releases of this midge in North America were made during a two-week period in June 1985 in Bozeman and Clyde Park, Montana, with Norm Reese and Noa Poritz, and in Glacier National Park, Montana, with the help of Dave Lange and Maura Longden. The released *D. capitigena* originated from parent material collected from *Eu-*

phorbia esula in northern Italy by P. Pecora. The extreme dryness of the season caused most of the eggs to desiccate before they were able to hatch. A few galls were found, indicating the midge's ability to use Montana leafy spurge in the field. Whether sufficient numbers of galls were formed to allow establishment and what the ability of the insect to over winter is, are unknown. We will release more midges next season (1986) and hope for less severe weather conditions. Through the use of *D. capitigena*, we hope to reduce the reproduction and spread of leafy spurge.

Another *Dasinuera* species (*D. capsulae*) has been under study by Pasquale Pecora in Rome. It galls the individual flowers within the inflorescences of leafy spurge plants. We expect to begin research in Albany on this midge during the next year (1986).

These insects and the others previously established in the United States by the USDA (*Hyles euphorbiae* and *Oberea erythrocephala*) will hopefully combine to produce sufficient stress to control leafy spurge. Despite the recognition that biological control of leafy spurge is a difficult proposition, we are optimistic in this undertaking because of the number of highly specialized insects likely to be available to us.

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Status of the leafy spurge hawkmoth – Potential for redistribution in 1985

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The leafy spurge hawkmoth, *Hy1es euphorbiae* L., is well established on leafy spurge at a site approximately 3mi. NE of Bozeman, Montana. Numerous larvae and pupae were collected during summer of 1984 and will be used for breeding stock to supplement field-collected larvae during redistribution efforts this July, 1985. Unfortunately we have found a viral infection in the field in a population of hawkmoths collected near Bozeman. If the disease is detrimental, the last thing we want to do is to redistribute an infected population of the moth to new areas, which might impair the moth's potential for increase and damage to the leafy spurge. At this time we don't know the effects of the viral disease on the moth or whether it accompanies most hawkmoth populations. Research is currently being conducted at Bozeman to determine the potential impact and seriousness of the disease. Thus, I am cautiously optimistic that we will have an ample supply of hawkmoths for redistribution this summer.

If the disease is not serious we will need to prioritize the allocation of the hawkmoth larvae because there will be a limited number available for redistribution. The first priority will be to redistribute the moth to designated individuals from key geographic areas within the Western Region (including North and South Dakota). The next priority will be to provide hawkmoths to remaining applicants based upon the date of request. Hopefully these moths will become well established and provide collection stock for redistribution to new areas in the future.

The collection and/or rearing of the hawkmoth will be synchronized to coincide with the Leafy Spurge Symposium, July 17 and 18, 1985. We will arrange to have styrofoam coolers and ice packs for the redistribution effort. We will attempt to provide a minimum of one hundred larvae per designated applicant to better assure adequate numbers for survival and mating. Larvae will be placed on bouquets of spurge and enclosed in the coolers for the trip to their new destination. A $20.00 fee will be charged to offset the costs for the cooler, ice packs, labor, etc. We will try to accommodate as many requests for the hawkmoth as possible.

A leafy spurge hawkmoth training session will be presented at the Leafy Spurge Symposium, which will cover areas such as hawkmoth rearing, handling, collection, release, and redistribution.

We thank all of you for your continued interest and support for biological control.

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Implementing biological control – How the Animal and Plant Health Inspection Service may help

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An important obstacle to greater utilization of biological control agents is lack of well-organized action programs to insure efficacious use patterns in the field. Through it's Plant Protection and Quarantine (PPQ) arm, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) is helping increase field use of biological control agents by implementing action programs against selected plant pests. Through mass production, distribution and evaluation of natural enemies, these programs often provide the link needed between research and field utilization. Current APHIS implementation projects are directed against biological control of the alfalfa weevil, Mexican bean beetle, citrus whitefly, silverleaf nightshade, Colorado potato beetle, and diffuse and spotted knapweeds.

APHIS participation in biological control has developed around either regulatory or grower management needs. In regulatory programs such as cereal leaf beetle and citrus blackfly, biological control tactics are used to suppress newly introduced pests of economic importance. In these instances, APHIS and the State agencies involved can assume overall leadership for mass-producing and distributing biological control agents. They can also cooperate with research, extension and grower groups for the necessary back-up.

As a part of a grower management project, overall management and policy making can reside in a coordinating group composed of members representing each active participating agency. The roles of the various agencies are as follows:

1. Federal and State agencies will identify the potential of biological agent for the management program and participate directly in devising project plans and procedures.

2. APHIS and State Departments of Agriculture, as the action agencies, will assume field leadership and be responsible for production and distribution of the biological agents. Industry involvement will be encouraged.

3. Research agencies and institutions will be solicited for back up and will assist action agencies in execution and evaluation at the field level.

4. Growers will participate by cooperating in field aspects and by sharing costs as the project develops.

5. Extension services will be solicited for an information education program so that growers and the general public understand the project and its contributions.

PPQ line personnel and cooperators will play a major role in survey and control procedures. Survey is needed to determine distribution and extent of targeted pests. Data will also be gathered on the presence or absence of control agents.

Control operations will center on the production and distribution of natural enemies. When feasible, field collection sites will be established and used as a source of natural enemies for redistribution. Use of alternative control strategies may be considered when and if circumstances dictate.

An APHIS-sponsored Biological Control Technological Review Group (BCTRG) is established to help select new biological control projects for implementation. The BCTRG is composed of representatives from PPQ, the Agricultural Research Service, Cooperative States Research Service, Extension Service, and the Economic Research Service of the U.S. Department of Agriculture and the Environmental Protection Agency, and National Plant Board. The objectives of the group are:

1. Evaluate and advise on the selection of biological control agents for cooperative biological control action projects.

2. Identify areas where agencies represented on the advisory group can contribute to the implementation of those pest projects selected.

3. Identify areas where additional research or development work on candidate pests is needed before the project can be implemented.

4. Provide a sounding board for outside agencies on the development of biological control action projects.

5. Advise on the degree of Federal participation and general time frames for phasing in and out of selected cooperative biological control projects.

Government and private agencies and institutions are encouraged to submit biological control preproposals to APHIS for evaluation as possible implementation projects. Preproposals should not exceed two pages and are used to summarize candidate projects. If further development appears promising, APHIS will request a formal proposal.

The following basic criteria must be addressed when preparing proposals:

1. Potential effectiveness and safety of organism demonstrated.

2. Methodology available for rearing, release, and recovery of natural enemy, and estimated cost.

3. Methodology available for evaluation of organism's impact.

4. Economic impact of the pest.

5. Other crop management practices likely to impact project.

6. Positive and negative factors likely to affect program implementation i.e., grower interest, pesticide resistance, rearing problems, mobility of natural enemy.

Proposals are then evaluated by the BCTRG in light of the following factors:

1. Significance of involved crop to U.S. agriculture.

2. Present or potential impact of the pest species and the extent of information available on the biology and economics of the pest.

3. Level of participation by cooperating agencies and groups.

4. Potential for project being carried on by State agency or user group following APHIS withdrawal.

5. Availability and acceptance of other control measures.

6. Geographical range of the pest problem.

7. Project implementation costs.

8. Potential for program success.

Preproposals may be submitted to the agency at any time. Formal proposals, however, must be received by December 15 of any given year to be considered at the subsequent BCTRG meeting.

All correspondence should be addressed to: Mr. Gary L. Cunningham, Senior Staff Officer for Biological Control, Technology Analysis and Development Staff (TADS), National Program Planning Staff (NPPS), PPQ, APHIS, USDA, Room 600A Federal Building, 6505 Belcrest Road, Hyattsville, MD 20782.

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Biochemical studies of the *Euphorbia esula* complex

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Pyrolysis mass spectrometry (PYMS) and starch gel electrophoresis were used to determine patterns of biochemical variation in the *Euphorbia esula* complex. These patterns of biochemical variation are being used to elucidate underlying patterns of genetic variation.

Pyrolysis mass spectrometry is a method that has been used for the determination of overall patterns of biochemical variation in several types of complex biological materials. Other workers have used PYMS in taxonomic studies of microorganisms and in studies of the relationship between the biochemical constitution of host plants and their susceptibility to herbivorous insects. We have conducted studies aimed at determining the feasibility of using PYMS to elucidate patterns of biochemical variation in the *Euphorbia esula* complex. These patterns of variation should provide information relative to the taxonomy of this group and their susceptibility to potential biocontrol agents. Analysis of spectral data by factor analysis, discriminate analysis and graphical rotation showed several distinct biochemical differences between *E. cyparissias*, *E. esula* (from Austria), and the 'Gallatin' and 'Teton' accessions from Montana. It was not possible to correlate these differences with differential preference of biological control agents because quantitative indices of the susceptibility of these accessions to biocontrol agents were not available.

Electrophoresis, the separation of proteins in an electric field, is being used to determine patterns of genetic variation of the *E. esula* complex. This procedure involved producing starch gel zymograms for several accessions within each of several populations of leafy spurge and then doing genetic analysis to determine the allelic basis for the observed banding patterns. This genetic data can, in turn, be used to calculate indices of genetic similarity within populations and genetic distance between populations.

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Evaluation of spring vs. fall original/retreatment combinations as affecting leafy spurge live shoot regrowth

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This field study located near Lander, Wyo. was established for accumulation of original/retreatment and fall vs. spring application data on leafy spurge. Four successive years of data have been collected since the study was established in the spring of 1980. This study is one of four experimental sites that were located in three Wyoming counties. Data on leafy spurge shoot and root control, forage production and soil residues of dicamba and picloram were obtained from these sites. Some of the data in this paper were extracted from Ronald E. Vore, Ph.D. Thesis, May 1984, University of Wyoming.

Original spring and fall treatments were made May 23, and September 14, 1980. Liquid formulations were applied with a 21.5 ft boom, 13-nozzle truck mounted spray unit equipped with Teejet HSS8004 nozzles delivering 25 gpa water carrier. The granular formulations were applied with a hand operated centrifugal granular spreader. Plot size for the original treatments was 21.5 ft by 258 ft with one replication.

Retreatments were applied across the original treatments creating a split-block design and were made May 29 and September 12, 1981; May 24 and September 17, 1982; and May 29 and September 15, 1983. Retreatment plots were 21.5 ft by 21.5 ft with two replications. The retreatments were 2,4-D amine at 2.0 lb ai/A, dicamba at 2.0 lb ai/A, picloram at 0.5 and 1.0 lb ai/A, 2,4-D amine (spring and fall applied) at 2.0 lb ai/A, and an untreated check. The retreatments of picloram at 0.5 and 1.0 lb ai/A were terminated with the 1981 treatment. The leafy spurge was in the bud to flower stage-of-growth and 4 to 18 inches in height during the spring retreatments and was mature and had shed most of it's seed when fall retreatments were made. Retreatments were applied with the truck-mounted sprayer used to apply the original treatments. The soil at this study site was a sandy loam (73% sand, 15% silt, and 12% clay) with 1.3% organic matter and pH of 7.6.

The area has been flood irrigated since application of original treatments. However, irrigation is not uniform in the study area. There was poor grass cover May, 1980 when plots were established. By September, 1981 grass was 20 to 24 inches in height and still green in treatment areas. Good grass cover has been maintained in treatment areas throughout 1982, 1983, and 1984. The grass species present in this area include intermediate wheatgrass (*Agropyron intermedium* [Host.] Beauv.), western wheatgrass (*Agropyron smithii* Rydb.), smooth brome (*Bromus inermis* Leyss.) and downy brome (*Bromus tectorum* L.).

Percent shoot control is based on reduction of live leafy spurge shoots per square foot recorded from treatment plots as compared to the untreated (check) plots. Shoot control data are presented in Table 1. The percent leafy spurge shoot control has decreased in most of the original treatment plots over the four-year period. There appears to be little difference in the effectiveness of the original treatments whether spring or fall applied. However, better shoot control has been maintained in the original treatments where picloram was applied regardless of rate or formulation. The reduction in shoot control is also apparent since the retreatments of picloram were terminated with the 1981 application. The 2,4-D amine retreatment applied both in the spring and fall (S & F) is more effective than only the one yearly treatment applied either in the spring or fall. Application of retreatments has maintained better shoot control than single treatment applications, except where the retreatment was picloram at 1.0 lb ai/A, over the original picloram treatments, in the spring study area. This is probably due to leaching of the picloram out of the shallow soil in this area. There is also considerable variation in percent leafy spurge shoot control between other treatments and rates of application, which may also indicate variation in soil and leaching of the herbicide out of the shallow soil profile.

The effects of dicamba granules and picloram granules on leafy spurge root weight at various soil depths were also studied one year after treatment application. Leafy spurge root control samples were taken on May 25, 1981. Ten core samples per treatment were randomly extracted in the spring applied dicamba granule and picloram granule plots. Core samples 4 inches by 24 inches were taken with a manually operated coring tool. Cores were then subdivided into 8-inch sections and screened through a 2-mm screen to separate soil and leafy spurge roots. Root segments were then counted and weighed. Leafy spurge root weight was greatest in the top 8 inches of soil and decreased with depth in all areas (Table 2). Comparison of root weight data and leafy spurge shoot counts indicates that root weight had no significant effects on shoot counts.

Data were also collected on the residual concentrations of dicamba and picloram, one year after treatment application, at various soil depths. Soil was sampled May 29, 1981 for dicamba and picloram residues, with six cores 2 inches by 24 inches being taken in the spring applied dicamba granule and picloram granule plots. The cores were subdivided into 8-inch sections, bagged, identified, transported to the laboratory and frozen. Samples were later analyzed by the Wyoming Department of Agriculture, Division of Laboratories, using gas layer chromatography. Dicamba residues were greatest in the top 8 inches of soil and decreased with depth (Table 3). Whereas, picloram residues showed no significant difference in concentration, regardless of rate of application or soil depth (Table 4). A comparison of dicamba and picloram residue data and leafy spurge shoot counts indicates that herbicide residues had no significant effect on leafy spurge shoot counts. Further, there was no significant correlation between herbicide residues and leafy spurge root weight.

Table 1. Leafy spurge shoot control

Original[1] lb ai/A		Percent Shoot Control[2]																		
		Retreatment lb ai/A[2]																		
		dicamba 4L 2.0			picloram (K salt) 0.5			2,4-D Amine (S & F) 2.0			Check				picloram (K salt) 1.0			2,4-D Amine 2.0		
		'82	'83	'84	'82	'83	'84	'82	'83	'84	'81	'82	'83	'84	'82	'83	'84	'82	'83	'84
(Spring)																				
dicamba 4L	6.0	94	85	89	100	91	85	88	95	93	92	64	29	60	100	99	96	80	70	69
dicamba 4L	8.0	88	90	89	100	95	95	99	100	100	95	81	34	26	99	82	75	90	78	63
dicamba 5C	6.0	89	69	81	100	95	80	87	98	97	92	73	86	34	100	100	87	99	97	83
dicamba 5G	8.0	92	78	92	100	94	93	100	99	94	95	89	75	32	100	89	79	93	94	94
picloram (K salt)	1.0	97	74	93	100	97	85	99	100	96	96	98	80	84	100	77	62	100	96	89
picloram (K salt)	2.0	100	79	96	100	100	96	100	100	100	99	100	91	88	100	75	67	100	94	99
picloram (2% beads)	1.0	98	67	93	100	68	85	93	84	88	93	79	95	74	100	81	18	100	89	89
picloram (2% beads)	2.0	100	69	89	100	77	86	100	88	97	95	100	93	78	100	24	15	100	95	95
Check	---	92	91	89	100	83	56	93	54	50	0	0	0	0	100	100	99	55	33	14
											19.8	*18.3*	*16.5*	*11.1*						
(Fall)																				
dicamba 4L	6.0	76	81	75	100	94	81	90	99	92	70	57	61	40	100	93	83	82	70	55
dicamba 4L	8.0	87	88	80	100	92	86	90	95	87	83	44	50	44	100	95	83	89	68	67
dicamba 5G	6.0	99	81	91	100	90	81	97	98	98	89	52	39	17	100	97	90	98	79	95
dicamba 5G	8.0	99	93	92	100	93	87	98	98	97	93	85	61	30	100	100	99	97	84	71
picloram (K salt)	1.0	99	87	89	100	92	83	99	99	99	95	90	81	64	100	99	95	96	74	56

Original[1] lb ai/A		Percent Shoot Control[2] — Retreatment lb ai/A[2]: dicamba 4L 2.0			picloram (K salt) 0.5			2,4-D Amine (S & F) 2.0			Check				picloram (K salt) 1.0			2,4-D Amine 2.0		
		'82	'83	'84	'82	'83	'84	'82	'83	'84	'81	'82	'83	'84	'82	'83	'84	'82	'83	'84
picloram (K salt)	2.0	100	96	97	100	97	93	100	100	100	99	99	93	79	100	100	100	99	93	92
picloram (2% beads)	1.0	100	91	98	100	96	83	100	100	99	99	100	96	88	100	97	89	100	86	96
picloram (2% beads)	2.0	100	86	95	100	86	73	100	100	100	99	100	94	88	100	91	66	100	85	95
Check		70	67	69	100	85	82	23	57	72	0	0	0	0	100	97	82	0	31	31
shoots/sq ft											*19.4*	*23.6*	*22.*	*14.8*						

[1]Original treatments made May 23 & Sept. 14, 1980; retreatments made May 29 & Sept. 12, 1981; May 24 & Sept. 17, 1982; & May 29 & Sept. 15, 1983. The retreatments of picloram (K salt) at 0.5 and 1.0 lb ai/A were terminated with the 1981 retreatment.

[2]Shoot counts May 27, 1981; May 24, 1982; May 29, 1983; and May 30, 1984.

Table 2. Effect of original treatments as evaluated by leafy spurge root weight at various soil depths.

Treatment[1]	Rate lb ai/A	Root Weight (oz/cu ft)[2] Soil Depth (in.) 0-8	8-16	16-24	Total
picloram. gran.	1.0	3.42	1.71	1.11	6.24
picloram gran.	2.0	3.44	1.32	0.90	5.66
dicamba gran.	6.0	3.80	1.48	0.78	5.72
dicamba gran.	8.0	4.52	1.50	1.23	7.25
Check	---	3.77	1.20	0.94	5.90
LSD (0.05) = 0.95 oz/cu ft					

[1]Original treatments May 23, 1980.

[2]Sampled May 25, 1981.

Table 3. Residual concentration of dicamba at various soil depths one year after application.

Treatment[1]	Rate lb ai/A	Residue (ppm)[2] Soil Depth (in.) 0-8	8-16	16-24	Total
dicamba	6.0	0.281	0.030	0.038	0.349
dicamba	8.0	0.341	0.250	0.001	0.592
LSD (0.05) = 0.331 ppm					

[1]Original treatment May 23, 1980.

[2]Sampled May 29, 1981.

Table 4. Residual concentration of picloram at various soil depths one year after application.

Treatment[1]	Rate lb ai/A	Residue (ppm)[2] Soil Depth (in.) 0-8	8-16	16-24	Total
picloram	1.0	0.020	0.040	0.052	0.112
picloram	2.0	0.030	0.037	0.022	0.088
LSD (0.05) = 0.050 ppm					

[1]Original treatments May 23, 1980.

[2]Sampled May 29, 1981.

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Evaluation of 2,4-D LVE as a setup treatment for low rates of picloram (Tordon 22K) for leafy spurge control

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Introduction

Leafy spurge is considered one of the most serious weeds in Wyoming. It has been reported that it infests 48,618 acres of rangeland and pastures in the State (Hittle 1983).

Picloram (Tordon 22K) is one of the most effective herbicides for controlling leafy spurge, however, the high cost of picloram has limited its use.

This experiment was conducted to evaluate the use of 2,4-D LVE as a setup treatment prior to light rates of picloram.

Picloram was applied at two times; immediately after 2,4-D LVE application, and fourteen days after 2,4-D LVE application for leafy spurge shoot and root control.

The experiment was established in the fall of 1984 at the University of Wyoming greenhouses at Laramie. Leafy spurge plants were established from root cuttings and then transplanted to 15 by 18 cm metal pots. Each of the thirteen treatments was replicated ten times in a randomized complete block design. The light duration in the greenhouse was sixteen hours, the average temperature was 22°C, and the pots were watered daily.

Data collected included visual estimation of injury (1 = healthy and 5 complete kill), shoot length (cm), root length, fresh weight of shoot and root (g), and dry weight of shoot and root. The dry weight was obtained by oven drying shoots and roots at 80°C for forty-eight hours.

This research indicated that 2,4-D LVE at 0.0625 and 0.125 lb a.i./A did not injure leafy spurge. Picloram at 0.125 lb a.i./A resulted in severe plant injury and at 0.25 lb a.i./A resulted in total control. Combination treatments tended to be less effective than picloram alone (Table 1).

Literature cited

1. Hittle, G.F. 1983. Wyoming's leafy spurge program 1978-1982. 95pp.

Table 1. Plant growth responses to the selected herbicide treatments.[1]

No.	Treatment (lb a.i./A)	Injury index[2]	Shoot length (cm)	Root length (cm)	Fresh shoot wt. (g)	Dry shoot wt. (g)	Fresh root wt. (g)	Dry root wt. (g)
1.	.0625 2,4-D LVE (D_1)	1	70.5	66.0	10.2	3.2	25.7	11.9
2.	.1250 2,4-D LVE (D_2)	1	52.1	62.7	17.0	5.0	29.0	9.3
3.	.1250 Picloram (P_1)	4	17.2	31.2	.6	.3	2.9	.8
4.	.2500 Picloram (P_2)	5	25.1	19.7	.5	.3	1.2	.3
5.	$D_1 + P_1$ (0 day)	3.8	34.9	72.6	8.6	2.7	13.6	3.4
6.	$D_1 + P_1$ (14 day)	4.1	32.0	70.1	4.5	1.4	19.7	3.9
7.	$D_1 + P_2$ (0 day)	4.5	32.0	56.4	2.5	.8	19.0	4.0
8.	$D_1 + P_2$ (14 day)	4.6	27.3	61.5	1.7	.8	21.0	4.6
9.	$D_2 + P_1$ (0 day)	4	38.1	68.6	3.4	1.0	17.1	3.2
10.	$D_2 + P_1$ (14 day)	4.4	29.9	62.0	4.2	1.5	19.4	3.7
11.	$D_2 + P_2$ (0 day)	4.4	28.2	84.3	3.1	1.2	22.8	4.5
12.	$D_2 + P_2$ (14 day)	4.8	27.9	68.1	2.1	1.0	18.0	5.6
13.	Check	1	44.3	81.8	10.2	2.8	36.0	10.8
	LSD (0.05)	0.52	10.45	17.95	3.45	0.96	8.70	3.09
	C.V. %	16.66	33.70	33.06	74.65	65.00	53.02	69.26

[1]Each value is an average of ten replications.

[2]1 = healthy, 5 = dead.

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Comparative treatments of fluroxypyr, dicamba and picloram for leafy spurge control

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A comparative trial was set up near Enterprise, Oregon to compare the efficacy of fluroxypyr (Dowco 433) (Starane), to dicamba (Banvel) and picloram (Tordon 22K).

The experiment was applied July 27, 1984 on leafy spurge in full flower. The experimental design was a randomized complete block with four replications of each treatment. Soils consisted of 11.2% sand, 63.3% silt, and 26.5% clay with an organic matter of 2% and a pH of 7.0. Applications were made with a 10-foot, 6 nozzle, hand-held boom, using 40 gallons of water per acre. Plots were 10 feet by 27 feet in size.

Visual evaluations were made June 8, 1985 and percent control was estimated. Fluroxypyr was found to have four times the activity of picloram when each herbicide was applied at 0.25 lb ai/A (Table 1). Leafy spurge remained in the vegetative state without any flower or seed production one year following all fluroxypyr applications. Fluroxypyr applications of 0.25 and 0.5 lb ai/A gave 60 and 76.3% control, respectively. Increasing fluroxypyr rates to 1.0 and 2.0 lb ai/A did not increase leafy spurge control greatly above the 0.5 lb ai/A application rate. Application rates of fluroxypyr at 0.25 lb ai/A controlled a higher percentage of leafy spurge than did 4.0 lb ai/A of dicamba.

This initial study comparing fluroxypyr, dicamba and picloram indicates that fluroxypyr has considerable activity on leafy spurge. Treatment combinations with other herbicides as well as sequential and timing trials should be conducted to further determine the activity of fluroxypyr on leafy spurge.

Table (1) Comparative treatments of fluroxypyr, dicamba, and picloram for leafy spurge control.

Herbicide	lb ai/A	% Control				
		Rep 1	Rep 2	Rep 3	Rep 4	Ave.
		No flowering of leafy spurge ---				
Starane	0.25	60	60	60	60	60.0
		No flowering of leafy spurge ---				
Starane	0.5	60	75	85	85	76.3
		No flowering of leafy spurge ---				
Starane	1.0	80	70	85	85	80.0
		No flowering of leafy spurge ---				
Starane	2.0	70	70	80	70	72.5
Banvel 4L	4.0	40	50	50	50	47.5
Banvel 4L	8.0	85	95	95	99	93.5
Tordon	0.25	10	10	15	20	13.8
Tordon	1.0	98	80	98	95	92.8
Tordon	2.0	99	97	99	97	98.0
Check	–	0	0	0	0	0

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Key-note address: The pay-off from 5 years of leafy spurge research

JIM WELSH

Welcome all of you to Bozeman, and to what I understand has been an extremely productive meeting at this point.

My assignment this morning is to give a keynote address that focuses on the issue of THE PAY-OFF FROM FIVE YEARS OF LEAFY SPURGE RESEARCH. Being the key-note speaker allows me to deviate considerably from that particular title. I would like to spend a couple of minutes with you this morning talking about my perceptions of investment in research because, undoubtedly, if you're talking about a pay-off some place along the line, then there must have been an investment in that activity earlier. To anticipate a tremendous pay-off for five year's of activity, addressing a problem that has taken as long as it has and as complex as it is to address, I think is probably being terribly optimistic if we're looking for a tremendous pay-off. I'd like to visit with you for just a few moments about at least the Montana perception of investment in research. Where I think we are going, where I think we have come from, where I think we are at the present time, and where I think we are going as far as research, not only in our state, but in surrounding states and nationally as well, especially in the agronomic area. Weed research in Montana, I believe, is a classic example of the development of a particular research area, both from past activities and for the future. I get to many meetings around the state, as I know many administrators do, and talk to people about the key issues. Without a doubt, during my five years in this particular position, the single most visible issue that we have had from the crops community, from the livestock community, from the environmental community, from the public lands community, and you can go right down the line, the single most visible and critical issue we've had is the weed problem. Until I took this assignment, I had never been particularly active in the legislative process. I can assure you that not only is this issue serious in the minds of the people that are producing the agricultural products, but it is equally serious in the minds of our legislative community. A tremendous amount of activity, debate, and discussion on funding and so on has also occurred in the legislative process in Montana. I know it's occurred in a number of other states in the region.

What are we, in fact doing and going to do in terms of addressing this particularly complex and difficult issue? Awareness of the problem is, of course, the first stage. The day before yesterday I had the pleasure of traveling with our president and two or three legislators to review some of our own land-holdings with respect to a particularly troublesome issue called leafy spurge. It's obvious to me that weeds are no longer a back-room issue. The legislators that were in that particular discussion were concerned not only with the question, “What can we do today in terms of helping the public sector to control their problems, but also what can we do in the future in terms of putting more resources into this kind of an issue which, in fact, affects such a wide segment of our total society?” There has been and will continue to be a tremendous awareness of the problem. I know Pete Fay, Mike Foley, Jim Story, and Bob Nowierski, as weed scientists, have worked very closely with our own public awareness system, the extension service, with various individuals in that area and with other public agencies to increase the awareness. It’s amazing to me still, how many people you can find in our area that really don’t know what a spotted knapweed plant looks like. But as you go out across the countryside and talk to people, knapweed, spurge, Canada thistle, and so on are still not readily identified and addressed in the minds of what I suppose you’d call the average citizen. And so we need to continue to pound on the awareness issue.

After the awareness issue has come on us we have become aware of the seriousness of spotted knapweed. If you don’t believe it is a serious problem, go over and take a look in the Bitterroot Valley of Montana. The whole western side is absolutely 100% infested, and please don’t quote me on this, because that is an overstatement to make a point. In all seriousness, if you look at that particular area, there is an incredible amount of the landmass that is covered with spotted knapweed, and we’re just now really becoming terribly concerned about the issue. I know our own weed scientists have identified new weeds that have just begun to make entry into Montana. It seems to me that if anything, we should be placing more emphasis on the question of how do we address the issue of new weed problems migrating into the state before it becomes a crisis issue. Unfortunately, our society is a crisis-oriented society. I think back to my own experiences in North Dakota, born and raised on a farm in the Langdon country area. I can tell you that until we almost got wiped out with stem rust, a problem that was on the minds of the scientific community but not an issue for farmers, it was sure tough to make key people aware that they ought to be pumping some resources into stem rust research.

We’re a crisis-oriented community, there’s just no question about it. I think somehow we have to move beyond that mentality. But assuming that that’s the case, it appears we have to move farther and faster in developing plans to address these issues in order to carry them out in a well-coordinated and efficient fashion, because I see fewer resources in the future. I can assure you that that part of the speech is not going to be particularly optimistic as far as additional resources; because I just don’t think they’re there. So in developing plans to address the problem, it seems that we have to figure out how to use our resources more effectively than we have in the past. The way we’ve approached it, and I know that the way many of you have approached it is not entirely unique. We have said to the legislature, “If we can get some additional funding for the research team that we have on board, and allow them to work more closely to their maximum capacity, then we will not have to add an entire new cadre of people for which we don’t have enough funding. We think we can do a better job with what we have in terms of the scientific personnel. That is the program that the legislature in Montana has followed as far as the weed research area is concerned. There are about four research scientists in the experiment station addressing the three areas and I noticed on the Symposium tee-shirt this morning the three areas of chemical, cultural, and ecological research listed. We feel that a team approach in a well-coordinated effort, with the personnel that we have available, is the route to go. The legislature bought onto that, not to the magnitude that we would have liked, but they did buy onto it and added some additional resources and supplied some technical help, extra work funds, and a little bit of capital equipment, and so on. Certainly not enough, but we have been able to do more than before. Nevertheless, it is a package that we can stand behind. We have an excellent scientific team. We continue to move forward both in the state funding and in the soft money to provide a total package that we think has gone a fair distance in beginning to address some of the weed control problems.

We have been active in working with the other agencies, the private sector, private landholders, with the cooperative extension service, and with the public media, to distribute the research information. Information doesn't do any good if it sits on the shelf. The scientific community in the area and the state has a, I'll put it frankly, has a heck of a bad reputation for developing information and not really getting it out in the hands of the people. In addition to the scientific work of research and development, we feel very strong commitment to work with the appropriate organizations, agencies, media, extension service, and so on, to be sure that this information gets into the hands of the people so they can use it. Generally, this is the approach that we've taken. I think it's been pretty effective. As I said, the program isn't of the magnitude that we'd like to have, but at least we think it's a step in the right direction for using the resources that we do have.

What do I see as far as potential resources, and when I'm talking about resources, folks, I'm talking about greenbacks. That translates into people, trucks and all the rest of it, but I'm really talking about money. What do I see coming down the line as far as additionally resources for this kind of activity? Let us look at our own state of Montana for just a moment. I've had the pleasure of traveling for the last 10 days to various research centers, private farms, and so on around the state. If I were terribly optimistic, I would tell you that the outlook is grim. Is that a reasonable statement? I think that's a reasonable statement. We are in probably one of the deepest droughts that we've had in the history of the state. I know our Canadian friends, the western edge of North Dakota and part of the northwest corner of South Dakota. It's a kind of a strange thing that this area seems to be blessed with a unique of set of environmental circumstances that not much of the rest of the country is dealing with at the moment. If you look at the kinds of bumper wheat crops that are rolling in from the Great Plains, from the central and southern Great Plains, you can see our dilemma. A good bit of our resources in this state come from a couple or three areas. One of them is agriculture and what I have just painted for you is not exactly the brightest picture in the world for the agricultural area. We also depend on a good part upon other natural resources like coal and oil. And I heard some discussion the other day that there is a possibility that OPEC may drop their oil prices to $15 a barrel. Now I will tell you that for every dollar that a barrel of oil drop, our state revenue drops by about $10 million. That may give you some additional insight into where I think we are. We are also looking at tourism and coal production as major industries, at this point in Montana, are weak. Back to agriculture, it isn't good anywhere. It isn't good in Kansas, even though you may roll in a bumper crop. Wheat is dropping at what, three or four cents a day? Something like that. So they are now getting down to where they're at least $1.50 below production costs with every bushel they raise. I'm generating a picture of gloom and doom, and that's really what I mean to do, but what I mean to tell you is that I think we have to take a realistic look at the whole card deck relative to what kind of resources we may have available to work with. I just don't think that in the state of Montana that we can anticipate an additional large influx of state dollars into a program, for instance, that may address weeds.

What about the national picture? I read in the Great Falls Tribune this morning is that the entire national budgeting process has just fallen apart again. This means that the best we can probably hope for on the national scene, which is where our formula funding, special grant funding, and all kinds of major components of the research program come from, is a continuing resolution. Now for those of you who don't know what a continuing resolution is, generally out of a continuing resolution the best you can hope for is a flat budget, which means that there will be no increase for next year based on this year. So we're looking at a flat scene there.

What about the soft money area? What about grants and contracts? Now interestingly enough, but at Montana State University, over the last 5 years, if you chart the grant and contract money at MSU, it's on a nice inclining slope. We have been picking up more grant and contract money from various sources, and I think this says something about the capability, about the way these people are putting their programs together, not only in the weeds area but in other areas as well, and so if I see a bright spot on the horizon as far as increased money, it's probably in the grants and contracts area. That, of course, carries with it its own set of particular problems and issues. For instance, the federal funding and so on is getting tighter and tighter and even decreasing.

I guess what I'm saying is that as we look at these programs, and as I talk with Pete Fay, Bob Nowierski, Jim Story, and Mike Foley about the weed research issue, I don't think that it's appropriate to tell them that they will have a tremendous number of additional resources to work with. I don't think that's all bad. We have operated under tight budgets before and we'll operate under tight budgets again. I don't think that's all bad, because I think it leads us to do some other things that we need to address and these are addressed in my closing comments.

What are the opportunities for the future? I think the opportunities are really wide open, but I think we're going to have to learn how to do it better, more efficiently, squeeze more mileage out of the dollars that we're investing. How can we do this? Well, again, I think that we're making a mistake by bringing additional large numbers of people or additional people on board and not being able to fund them. I really think that's a mistake and I think we've done it over the years in the agricultural experiment stations around the country. The way to expand programs is add more people. In my opinion, the way to expand programs is to do a better job of supporting the people that we've got on board and let them work to their maximum. We need to provide more support for them. We need to provide more technicians, more capital equipment, more travel money and so on. But I don't think, at this point, it's in our best interest to bring more scientists on board. Not because we couldn't use them, but because I don't know that we will be able to support them.

Second, and I feel very, very strongly about this, is that I believe that we can make a lot of mileage with a stronger cooperative effort than we have had in the past. I think this meeting, yesterday and today, and under the administrative leadership of Don Anderson, and with an issue that is as vital as leafy spurge is, as the way you have come together is a classic example of what I'm talking about. There's plenty of work out there for everybody. And the single most frequently asked question I get, especially when I visit with legislators is, "why are you doing the same things that they're doing in North Dakota?" And the answer is that really we're not, but it isn't always very visible that we're not. I think this kind of an activity will become even more important in the future than it has in the past, you've got to figure out how to do it better if you don't have more resources to work with. You're just forced into it. I think we can. I just had a conversation with Don Anderson about 2 minutes before we started the program this morning. We will have an entomology position open at the Sidney Montana Research Station. Now I don't know whether all of you know where the Sidney station is. How may people know where the Sidney, MT station is? It's very close to North Dakota. Right across the Montana border on the other side is a little operation called Williston. It seems to me that what we really need to do, and I just visited with Don Anderson about this, is to sit down and take a look at that open position, take a look at the Williston-Sidney relationship and figure out how we can do a better job down the line of staffing centers, the key issues associated with that particular area. The Sidney operation concentrates primarily on, or a good bit at least, on irrigated agriculture and the Williston operation concentrates a good bit on the dry land agriculture. That's what makes a natural mix for that particular area of both of our states. I think we are going to have to just do more of that. I could down through the list. But I really believe that this will be a key to the continued success and improved output of the research community and the extension communities as we look at problems like this.

A third area, and I just don't know how everybody feels about this. The Ag Experiment Stations have traditionally not had a tremendous track record in the competitive funding arena, that is in the soft money arena. Partly because we have always had a pretty solid base to work with. You know you have your experiment station base that's state appropriated and you have the CSRS, the formula funding coming in from the federal side and so on. So it's been a fairly stable base, and we will all obviously work to continue to maintain and expand that base. But I see our scientific communities having to simply become more competitive in the soft money arena. I just think we're going to have to do more in the soft money arena if we're going to continue to support and develop our programs the way we should. And that, then leads to the whole area of grant writing, to the whole business of how to be competitive with other individuals across the country, and so on. Our track record is improving and we do have the capacity to do it. As we bring these young scientists on board and as we move forward in the next 10 to 20 years, my prediction is that the Ag Experiment Stations in this country will become increasingly competitive in the soft money arena. I really believe that we will be able to do that.

So that brings me, then to the final statement about what I think the pay-offs are. I really think that the pay-offs in this activity are incredible. I think you've seen some tremendous pay-offs at this point, even though the title says 5 years, obviously there is a longer history than 5 years in this business and we know that. We know that in biological research it's not always easy to run a crash program and generate something in 6 months, as it is in the bacterial arena, for example. But in the biological world where you're dealing with critters like leafy spurge, the hawkmoth, and so on, things that tend to take a long time to unravel. Often times people become fairly impatient with that. I believe the pay-offs have been incredible, the fact there's this much interest in this subject at this point is some testimony to that. Certainly we are seeing more interest on the part of the producers and on the part of the public land managers and so on in addressing these issues. I believe that we are standing on the edge of really some very, very exciting and tremendous pay-offs and I think we have had them up to this point. In my way of summarizing this, I believe, despite the funding comments I've made, I believe the future is bright. I think we have some really exciting things that we can do. We may be forced into doing some things a little differently than we have in the past, but I really believe that there are some exciting things that we can do and I think track records will show that the pay-offs and investment in this kind of activity are really incredible. Best wishes to you for the rest of the program. Unfortunately, I will not be able to stay with you for the entire day. Mike, thanks for having me on and if there are any questions or comments if you want to take 30 seconds, I'll be glad to try and answer them. Thank you very much.

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Bounty programs – An effective weed education tool

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Introduction

Leafy spurge (*Euphorbia esula* L.) is one of the most troublesome weeds on rangeland in Montana, North Dakota, and Wyoming. Once established, leafy spurge is difficult to control due to an extensive root system and efficient means of sexual and asexual reproduction.

Rangeland is extensively managed and relatively inaccessible. Often, these conditions enable weeds to establish and spread before they are recognized. Once large acreages are infested, prohibitive costs prevent large-scale use of herbicides. Thus, the key to weed control on rangeland is early detection and treatment.

Creative educational programs that promote awareness, identification, and control are needed to stop the spread of weeds on rangeland. In 1984, a weed "bounty program" was implemented in Stillwater County, Montana. The approach used in establishing this program will be evaluated and guidelines for developing similar programs will be discussed.

Approach

The weed bounty program in Stillwater County was initiated to stop the spread of spotted knapweed. However, similar programs could be developed to address any problem weed on rangeland. The objectives of the program were: (1) to increase public awareness of spotted knapweed; 2) accurately locate and map all spotted knapweed infestations; and 3) control spotted knapweed infestations that were reported.

Guidelines:

Guidelines were developed by the county extension agent and weed supervisor to involve young people with the program. Posters and newspaper articles carried photographs of the "wanted" weed to help youth identify the plant. Live plants were on display at the county extension office. Young people were paid a $5.00 bounty for reporting each spotted knapweed infestation that was not previously plotted on the county weed map.

An additional $50.00 was paid if the “bounty hunter” could persuade the landowner to control the infestation.

In addition, only one claim per ranch could be filed unless infestations were more than 1/4 mile apart. The “bounty hunter” received the same reward regardless of the size of infestation. These two guidelines insured that all infestations were reported to the county extension agent or weed supervisor and located on a map. They also encouraged the “bounty hunter” to work with the landowner to control the infestation. To aid their effort, county spray equipment and control information were provided to “bounty hunters” and landowners. Throughout the program, the county agent and weed supervisor were available to confirm infestations, provide technical assistance, and evaluate control efforts.

Funding:

Funds for the bounty program were obtained as an educational appropriation from the county weed control budget. The program was administered by the county extension agent and weed supervisor.

Program results

The first year of the bounty program was very successful. More than 65 people were directly involved with the weed control effort. Participants included 14 “bounty hunters”, their parents, agricultural producers, and state and federal employees that assisted the county’s effort to control spotted knapweed.

Thirty-four spotted knapweed infestations were located and recorded on the county weed map. Infestations occurred on private, state, railroad, and federal lands. This base map will be a valuable planning document for future efforts in the county.

Landowners and “bounty hunters” applied control measures to 20 of the infestations during 1984. The county has continued to work with landowners in controlling the spotted knapweed which occurred on the 14 remaining sites in 1985. Publicity concerning the program increased weed awareness on both a county and regional basis.

Program cost effectiveness:

It would have cost an estimated $5,670.00 to have county employees locate and control the spotted knapweed infestations. The total cost of rewarding young people through the bounty program was $1170.00 which included the $5.00 “finders” fee and the $50.00 “control” bounty. This program resulted in a savings of $4500.00 to the county weed budget. There will also be long-term financial benefits achieved through the education and involvement of young people in the weed control effort.

The bounty program was continued in Stillwater County in 1985. Since most of the spotted knapweed infestations had been located in 1984, only 6 new infestations were found in the county. This indicates that the 1984 program successfully located and controlled most of the existing infestations in the county.

Discussion

The success of the weed bounty program in Stillwater County as an educational tool is reflected in the following statements by young people who participated in the program:

> “.... I learned how to identify spotted knapweed and how it spreads to infest new areas.”

> “.... I think it’s a very good program for everyone. It does the county a lot of good and it’s an easy way to make money.”

> “.... Once you become a ‘weed fighter’ you can’t drive down the road without looking for weeds!”

The success of the program can also be measured through its endorsement by other extension agents in Montana and surrounding states. Six counties implemented bounty programs in 1985 in Montana. Although guidelines adopted by these other counties were similar to the model program in Stillwater County, some changes were made to fit needs and objectives of the community. In Teton County, funding for the program was obtained by the Soil Conservation Districts working through agricultural dealers within the community. Youth organizations, such as boy and girl scouts and 4-H clubs, were encouraged to participate. In addition to a monetary reward, plaques were presented to the group locating the most infestations. As further incentive for the program, a $100.00 reward was offered to the person who located, mapped and reported the largest weed infestation.

Control of weeds in residential areas presents special problems since herbicide use is restricted. Without control measures, these infestations continue to serve as a source of contamination for the surrounding areas. Wheatland County adopted a bounty program for locating, mapping, and controlling weed infestations in residential areas. Guidelines for the program included a $5.00 reward for locating and reporting weed infestations and $0.50 per pound reward for the weed if it was pulled with part of the root intact. People of all ages were encouraged to participate in the program which increased the educational aspects of the program.

Guidelines for establishing bounty programs

Based on the results of weed bounty programs in Montana, the following guidelines have been established to aid the development of similar programs in other areas.

* The county extension agent, weed supervisor, or other key individual or group within the county must be willing to commit time and energy to the program. This is especially critical during the first year.

* The amount of bounty paid on a weed will be determined by the number of infestations in the county. For example, weeds that are just starting to invade an area should have a larger bounty than weeds that are more common.

* Utilize bounty programs as public education programs within a community.

* Publicize the program through a variety of media channels to promote enthusiasm and public awareness.

* Involve federal and state employees in monitoring the program on public lands.

* Success of the program will be influenced by the nature of the target weed. The selected weed should be a potential threat to the area and common enough to promote enthusiasm for the program, especially the first year the program is implemented.

Summary

Citizens in a Montana county used a weed bounty program as an educational tool to promote awareness, detection, and control of spotted knapweed on rangeland. Many people became involved with the weed control effort, weed awareness was increased, weeds were controlled, and the program proved cost-effective. The success of a bounty program is influenced by: 1) the enthusiasm and innovativeness of the county extension agent, weed supervisor, or key individual or group in the community, 2) the choice of the weeds selected for the bounty program, and 3) good media coverage of the bounty program. With proper planning and organization, weed bounty programs can be used effectively in other areas.

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The spurge program in Stillwater County, MT

WAYNE PEARSON

Weed Supervisor, Columbus, MT

One of the things I should mention, we limited our weed bounty program to ages from 10 to 18 years. I'm not real sure that was a wise move. Last year we had some mothers come in with little kids who couldn't even write and signed up for this program. And we had some of the most excited mothers running around that county. Then on the other end of the spectrum, this year, just here last week I had an older lady stop me and said will you bring me one of those spotted knapweed plants that everybody's talking about. I'd like to know what they look like. I said sure, I'll bring one in so you can see what all the fuss is about around here. And as I started on down the street, she hollered at me and said but don't bring one that's got any seeds on it. And she was 80 years old. Maybe we should get the older people to help fight weeds also. I think that's great. You can't limit it to just one bunch of people. When you get into a weed awareness program, you've got to have everybody in the whole county or the whole state involved in this thing, if you're going to make it work.

One other quick comment on our program for this year. Last year we had 34 claims filed, and that pretty well covered every spotted knapweed patch that we had. This year, we have had less than 20 claims so far. We were going to cut the program off July 1. We didn't have our budget used up and there are other patches showing up out there along roads, so we extended it on and it's still open. We often have kids come up to me and say do you know where I can find a knapweed to turn in? They can't find them now and that's the same bunch of kids that were real eager hunters last year. So we have accomplished something. We don't have as many spots to be recorded this year as we had last year. I think it's great.

What I'm supposed to be talking about today is what we are doing in the leafy spurge arena. To start with, I'm the first and only supervisor for Stillwater County, so we kind of started at square one trying to figure out what we wanted to do. I started 11 years ago. During that time, I've probably met with all the frustrations of any weed supervisor lack of funds, equipment, environmental concerns, and all the things that everybody is concerned with. And during that time, we've probably tried just about everything in the book and quite a few things that are not in the book and probably never will be. We read everything we could find that Wyoming was doing and Harold Alley and George Hill and all the pros down there kind of setting the pace for some things. We copied a lot of their things and kept moving along. I can truthfully say that after 11 years of actively fighting leafy spurge, we don't have a lot more spurge now than we had when I started. We really haven't gained on it, but we've sure controlled a lot of spurge. It doesn't sound like we've been doing much when I make that statement, but we've killed hundreds of acres of new patches of leafy spurge. We haven't killed a single patch that was here to start with. They're still there and I suspect they're going to be there for a long time. We kill the tops, but we never get the root system. We catch new spots and kill them because they haven't got a root system down yet that you have to fight with. You can control the spread. So, that's kind of what we're looking at is more of a stop the spread type of thing rather than really trying to control or kill that old spurge. Back 11 years ago when we started, we started with the Tordon program and we found out that sure enough if you put out 2 lbs. of Tordon per acre, the next year you'd have very little spurge and lots of grass. Well, this looked great, and this went on a couple years. So that we'd started our public awareness hitting the local press and really pushing the issue and the ranchers would come and look at our test plots and all the things we were doing and we determined that was the way to go. We figured that applying 2 lbs. of Tordon on the leafy spurge and you would have the problem solved. We decided we were going to get every acre of spurge in Stillwater County and soon as we got that done, we'd be in good shape.

About this time, because of the awareness thing, we had a lot of people calling up. And they'd say isn't there a weed law? Can't I force my neighbor, or will you will force my neighbor to clean up his leafy spurge? Then I can start working on mine. Well, probably he had as much as the neighbor, but he felt if we made the neighbor clean up first why then his would be a little easier or something. That's been a problem for quite a while. We did address that in our new weed law that goes into effect in October.

We decided we were going to develop some kind of program to get on this weed thing. So the first move we made was to contact the state, they had a program going about then where we could get a plane in there with the infrared cameras and fly the area. We did that and it turned out real well. With that infrared you can pretty well pick out the spurge if you have a professional interpret them for you. We had our area mapped in short order where those spurge areas were. Then we called a meeting out in the spurge country of the ranchers and we hung these maps up, these big infrared pictures on the wall and everything looked real impressive. So we had the meeting, discussed the problem, and you know every rancher in that area that we contacted that has leafy spurge showed up at that meeting, except one and he sent his hired man cause he couldn't make it. So that shows the interest that the people have in weed control if they had an opportunity to do something.

As a result of that meeting, 13 of those ranchers decided to get a helicopter in and apply Tordon pellets on the area and really clean things up. The 13 ranchers we got together called in a helicopter and we put this program together and it was quite successful. Next year we did the same thing. And boy we really got things going now. But then things kind of started to happen, the helicopter pilot crashed and was killed, and that kind of stopped that a little bit. Then we started looking at the things that we'd been doing three or four years before, and evaluating them, and here was the spurge coming back just as big as it ever was. Well, right away the ranchers started backing off, saying well we can't afford it, this $114, which was the average cost of that program per acre. We can't afford that every year on this rangeland. Well obviously they couldn't, because we didn't really realize that it was going to come back.

So that kind of changed the whole picture then. We had to reevaluate, decided which way we were going to go on this thing. They were still willing to do something. They still wanted to fight it. So then we went into a program, a prevention type program, where we were only going to work those areas around the basic infestations that had been their 50-60 years and keep it from spreading. And that worked great. We did that for a year. And we got good results. We're killing spurge. But by the second and third year after that program, why we started deciding that was pretty futile effort with all this seed source we had down through there and we had quite a few acres of really prime spurge. As long as that seed was there, and we had deer and birds and everything spreading that seed, we were going to have quite a problem just trying to keep ahead of it, just trying to keep it from spreading.

But the interesting thing, right when all of this was going on, we had one rancher setting right in the middle of the worst of it, wondering what all the fuss was about. He was an old-timer and he just couldn't buy our programs. But he was running sheep and there wasn't a spurge on his ranch. From the infrared, you could pick up his ranch, and you could walk over and look at it and there wasn't a yellow spurge on it, but it was loaded with spurge, it was there, but it wasn't blooming. Well, occasionally you had a few blooms but never went to seed on that ranch. In fact he was complaining that at the time his lambs weren't as heavy now as when he had more spurge. We started thinking about this thing so we started trying to convert a few cowboys into sheepherders, and if you every tried that, that's tough. But gradually, they started calculating the cost of $100-acre Tordon and looking what that guy was going over there making a nice profit, and not spending money on chemicals. He spent a little, in areas the sheep couldn't get to. He used it to clean up. He wasn't opposed to it. But they started looking at his program and so one by one they started falling into line. And every year since then we've added one or two ranchers. This year I added two that picked up some sheep. Next year I've got one already committed that's going to go with sheep. We've got one small tract owner started this year. He fenced his 10-acre tract, but with all the spurge down there, he thought it was kind of pretty, but everybody else was complaining about it, so he fenced that and put a few sheep in there. I was by there last week and the grass is taller than the sheep in there and the spurge is taller than the sheep, but there isn't a yellow blossom in that whole patch, they've got it. And that's really what it's all about. We get comments, you know, saying sheep don't kill spurge; you're just wasting your time. But neither does Tordon in those old patches. And when you look at it, those guys are making a few bucks with sheep and the guys who are spreading are spending $100 an acre. So you know, it's hard to justify that economically to these ranchers that are in hard times. Now this year, of all the years, the guys that are really surviving up there pretty well are the guys with sheep and leafy spurge. That old spurge is down 20 feet and growing well and it's cheaper. They're eating it like crazy and getting fat. His neighbor with nice clean rangeland that he's kept cleaned up all these years with cows and grass, the grass is dried up and gone, and his cows are headed for the market. You know, maybe we should be looking at this leafy spurge in a little different light and making use it, since we can't control it anyhow. Well, I shouldn't say we can't control it, we can control it. We can't kill it. But, maybe we should be changing our program to fit their problem. Rather than trying to change that problem, especially in economically hard times like Jim Welsh was just telling us about. The research that Pete Fay has done has proven that sheep will do well on leafy spurge. The lambs that weaned off the leafy spurge 5 to 15 lbs. heavier than they do on straight grass, and I understand we are going to have a speech later on today on sheep, so I better not get into that. But you know maybe we're approaching this thing the wrong way. Now I'm not saying go out and plant leafy spurge, but I do think these areas that we have a big problem with that we can't kill in established areas, we can keep them from becoming a problem by keeping that seed off from it, while we're spraying the edges and keeping that cleaned up and preventing the thing from getting out of hand until we get a better method of control.

Now that's our program in Stillwater County right now, trying to just contain the thing and keep it from spreading. We have probably more acres of spurge right now than we had when I started just because it's grown along the Yellowstone and the Rosebud and Fishtail creeks and all the different rivers and streams here in the county, in areas that we can't spray. It's in the brush and thickets and things that are difficult to control and we have that certain breed of problem with that spreading. The old areas are still there like I say, although they're not seeding. The ranchers aren't being infringed on areas and encroaching on them anymore because we stopping the new stuff.

So we're kind of in a containment situation at this point. We're now looking at islands and the fishing accesses. We have a program going today in fishing accesses, with goats. We take a trailer load of goats out and dump them in a fishing access. We tie them to a tree somewhere in the middle of a leafy spurge patches and turn the rest loose. The other goats graze around that area and stay close to the ones that are tied. The horse trailer we leave it there in the access with a little wire pen right behind it, an enclosure, a few panels that we shut them up at night so that they don't have to be watched. In the daytime, the Fish and Game crews are taking care of them right now. When they're in an access area doing some work they just turn the goats out and put them in at night. And when they move to a new area, we move our goats. We made a video tape just last week on the thing that's quite interesting, showing what they can do and the Fish, Wildlife and Parks is actually using that as a selling tool. We have them in the video and we're working with them closely on it, and hopefully that will become a state program. And if it does, we'll be hiring a full-time or several full-time goat herders that will just comb the fishing accesses... I know it sounds funny, but we do crazy things in Stillwater County. But it's working. And the video tape that we took just for a demonstration purposes, I guess, we turned a few goats out one at a time and put the camera right on them to see where they would go when we turned them out of the pen. Four goats, one at a time, went out and the first thing they did was grab leafy spurge and vigorously ate it, they just didn't nibble it. They were pulling that stuff and really going after it. About 15 minutes later we came back and took some pictures of what they were grazing, and by then they were taking a bite of spurge and a bit of old wild rose bushes or a weed or brush or anything in there. They're eating very little grass. A goat doesn't like grass particularly when they have brush to pick on. This impresses the Fish and Game folks because they had more choppers in there trying to thin the brush in their accesses anyhow. So I think we're going to make that work as a tool for cleaning up those areas that are a problem, that we can't get into it with chemicals, can't mow, and can't chop because of the nature of the place. We've had about 12-15 goats on an island there at Columbus for 2 years. We leave them there year around. There's 42 acres on that island just totally covered with spurge, and there hasn't been a blossom on that island in 2 years. So, you know, it's real effective. They go into the brush and it's not overgrazed. The grass is still better than it was because they won't eat much grass. But they'll go into the brush where it's the thickest where a sheep won't go.

That's probably enough of what we're doing there. We're into biological as Norm Rees told you yesterday. We had four releases in our county of insects that we're working on. I think that is a tool of the future. Norm would be the first to tell you that success is down the road a ways, so we can't depend on that cleaning up the leafy spurge just overnight. But we need that and we need everything we can think of. The biggest thing that you can do right now is to get all the people working with you just like we were talking about with the ransom program. Get people aware of your problem and through the local press and through the media and whatever, any kind of a program that you can get people involved. The county weed crew can't possibly take care of the weed problem in any county I've ever seen. It's just too big of deal usually for a weed control program with the county. But if you can enlist the help of all the landowners and get them a bit excited about the thing and aware of the problem, it'll work. Now you can't go out there and twist their arms, say we're going to force weed laws on you. You can make all the laws you want, and it's not going to work. I told our people down there when they were trying to get me to force that weed law. That I just was not the type of person play The Enforcer and go out and threaten folks. Because I just don't like to be threatened. I'm a rancher, and I don't want somebody telling me how do to things, even if they're right. You know that attitude. But you can lead people into programs and make them develop their own programs, help them develop their programs and make them want to do these things. We have got a program in Stillwater County, it's working great and I've never tried to force anybody to take care of weeds out there. From the peer pressure from the neighbors and just one guy succeeding and everybody else follows along, and it's working real well. We've got a long ways to go, we're not the perfect county by any means, but we do have some pretty good things going.

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Management guidelines – Rangeland weeds

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The leafy spurge control research effort has produced a lot of good information in the past five years. Research is continuing on chemicals, biological, and other control methods – all in an effort to find a way to get this major weed problem under control. A separate effort has been put into awareness programs in each state. Montana State University has had awareness and education projects putting on tours and programs throughout the state for five years. The other states with leafy spurge infestations have also been working hard on education programs. I think we have seen the awareness in each of these states become very high in the last three years. Most ranchers are concerned about leafy spurge and want to control it. Now we are faced with a new problem. Research is continuing, but there is no magic potion or insect to tell ranchers to use to wave good-bye to leafy spurge forever; however, we do have several tools to choose from. Tordon herbicides have shown to be the most effective chemical; but, retreatment is required, and we are finding results can be dependent on soils and other conditions. There are currently four different rate/retreatment schedules to choose from to gain 95%+ control in a three-to-five-year period. Since the seed is spread readily, new patches seem to pop up in new places each year. As one rancher said to me last week, "It requires persistence with a capital 'P' to control leafy spurge." If a ranch has large acreage of leafy spurge, where do you know where to start with a control program?

Researchers are making progress with the biological control effort with insects, and I hope to see this continued. Unfortunately, there is not an insect available right now that will gain on a spurge problem. The leafy spurge hawkmoth redistribution at this symposium is promising. Sheep control is quite promising from a containment standpoint and can really help a control effort on a ranch. There are some predator and management considerations with this control method.

We have several tools--not one is perfect. We have ranchers that are aware of the problem and have gone out to take care of it. Because there is no cure-all, many ranchers have not felt they are making progress and feel frustrated and confused on what they really should be doing. On top of that, their neighbor does not control the leafy spurge, and his areas are being reinfested. They have become overwhelmed.

There is an answer to all this. First, land managers must realize (and face) that it is going to be a long-term effort utilizing all the tools currently available. Second, a step-by-step approach should be implemented to develop a plan of action for an infested area. Third, cooperative efforts between landowners, public and federal agencies need to be organized. Each ranch has a unique leafy spurge problem and requires different management. We, at Dow Chemical, are in the process of developing guidelines to help land managers sort out the problem with a management plan entitled:

“Management Guidelines – Rangeland Weeds”

Objective: To set forth a series of guidelines that will reduce the confusing and frustrating problem of leafy spurge control to a systematic programmed approach and which makes optimal use of available resources.

The guidelines were developed with this outline plan of approach.

I. Evaluate Range Weed Problem
   A. Map
   B. Collect Data
II. Set a Budget
III. Set Priorities
IV. Examine Control Methods
V. Keep Records

I. Evaluate range weed problem

This is the major part of the program. It is important for a rancher to see the “big picture” of the problem. What is it doing to the ranch now and where is it going?

A. Map

Each ranch should have a mapping system. It need not be complex or time consuming. Some ranchers like the topography maps, others the aerial photos from ASCS. Most ranchers have a map in their heads; but it is important to have it down on paper to truly evaluate and plan.

B. Collect Data

Each pasture will be evaluated for several things important to making a decision on a control program. We will call each fenced-in area a unit. The following will be recorded unit by unit.

1. General Range/Pasture Condition
   a. Use of Pasture
   b. Pasture Ownership
   c. Soil Type
   d. Vegetation Present
      - Trees
      - Brush
      - Adjacent Crops

e. Aquatic Characteristics
    - Irrigation
    - Waterways
    - Standing Water
    - Drainage

f. Pasture Productivity Rank

g. Pasture Condition

h. Terrain

i. Is this unit on the perimeter of infestation?

j. Has the spread from this unit threatened a highly productive unit?

2. Weed Infestation Analysis
    a. Degree of Infestation (1 = 10% to 10 = 100%)
    b. Type of Infestation (patches or solid)
    c. Density of Infestation
3. Source of Infestation

II. Set a budget

III. Set priorities

This is important if every area cannot be managed each year. Which area will give you the most long-term effect and use of your time and money?

IV. Examine control methods

A. Chemical
   1. Rates
   2. Application Method

B. Biological
   1. Insects
   2. Sheep

V. Keep records

To record each year's control method, keep track of results and make new plans.

Note: A workshop was held in Billings, MT in March, 1985. Four people from the states of Montana, North Dakota, Wyoming and South Dakota attended representing university, extension and federal agencies. They helped us refine and add to the above data collection.

Computer

A computer program has been developed to sort the data collected in Section B listed above. It will print out priority and control method recommendations and hard copy records for current program and retreatment schedules.

Model Ranch

This program will be tested and evaluated on a model-ranch basis in 1985. Currently, there will be two in Montana, one in North Dakota and one in South Dakota.

Final

"Management Guidelines – Rangeland Weeds" is still in the initial stages. We will be making conclusions this fall after the model ranch programs and changes are made. Again, we want to help ranchers and land managers:

- Develop a plan to decrease frustration and confusion
- Utilize money effectively
- Choose appropriate tools
- Protect rangelands and the environment

Please feel free to contact your Dow representative with questions or comments on this program.

Western Montana	- Great Falls	- Steve Saunders -	(406) 453-4647
Eastern Montana	- Billings	- Mary McKone -	(406) 656-7751
North Dakota	- Fargo	- Robin Merrill -	(701) 243-8161
Wyoming/S. Dak.	- Spearfish	- John Kitchell -	(605) 642-7513
Colorado/Utah	- Aurora	- Norma Hogan -	(303) 337-3177

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Controlling spurge with Tordon

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Considerable herbicide evaluation for the control of leafy spurge has been conducted since the introduction of the phenoxy herbicides in the early 1940s. However, the effort put forth by the states of Montana, Wyoming, North and South Dakota, and Nebraska since the first leafy spurge symposium held in Bismarck, N.D. in 1979 has reached unexpected proportions.

Joint research proposals submitted to the Old West Regional Commission was funded to support additional research in the five state commission area. The Old West Regional Commission grant was followed in 1982 by USDA research grant through specific cooperative agreements with the Agricultural Experiment Stations of North Dakota, Montana and Wyoming to continue the research. Practically every potential herbicide and/or combinations have been evaluated for their potential use to control leafy spurge and its spread.

As of the preparation of this paper there are four herbicides that are suggested, in most states, for use on leafy spurge. The herbicides Roundup (N-(phoshonomethyl)glycine), 2,4-D (2,4-dichlorophenoxyacetic acid), Banvel (3,5-dichloro-o-anisic acid) and Tordon (4-amino-3,5,6-Trichloropicolinic acid) along with the combination of Tordon/2,4-D and Banvel/2,4-D are suggested at various rates to fit specific sites and/or locations.

Tordon as either the liquid formulation (2 lb a.e./gal picloram) or the pelleted formulation (2% pellet) has consistently resulted in the highest percentage leafy spurge shoot control without resulting forage (grass) damage.

Seven years of research comparing the effectiveness of picloram rates, ranging from 0.5 to 2.0 lb a.e./A in a repetitive treatment series, has provided data whereby suggestions as to rates and/or repetitive treatment series can be formulated to fit almost any type of leafy spurge infestation and economic consideration.

Picloram applied at the maximum label rate of 2 lb a.e./A, either as the liquid or pelleted formulation, should be expected to maintain 90% control for 4 years before retreatment may be necessary. An application rate of 1.0 lb a.e./A has maintained 84% or better control for 3 years. The 0.5 lb a.e./A application will have to be retreated for 2 to 3 years to obtain control in the 90% or greater range. (Tables 1 & 2).

From the research with picloram and/or the combination of picloram/2,4-D, Dow Chemical U.S.A. research, sales and consulting group have developed guidelines for the Northern Range and Pasture leafy spurge control program.

The guidelines are presented in Tables 3 through 6. The maximum rate of picloram application, 21b a.e./A of either the 2-lb/gal liquid or the 2% pellet is suggested for spring treatment with the pellets being suggested for fall treatment. The high rate is for scattered infestations, isolated patches and inaccessible areas. This rate is expected to maintain 85-90% shoot control for 3-4 years. A retreatment of 1 qt. of Tordon 22K or 25 lb/A of Tordon 2K should be applied when shoot control drops below 75%. Control from the original treatment may vary due to soil type, moisture, etc. (Table 3).

The 1.0 lb a.e./A rate is for scattered infestations, isolated patches which are accessible to easy retreatment. The 1.0 lb a.e./A will maintain 85-90% shoot control for 1 to 2 years. A retreatment of 0.5 lb a.e./A is to be applied when shoot control drops below 75%. (Table 4).

Large uniform infestations, accessible to easy retreatment, where leafy spurge is growing on rocky, shallow, low organic matter soils can be treated with the low rate of 0.5 lb a.e./A of Tordon. It is necessary to retreat with the 0.5 lb a.e./A rate for 2 to 3 successive years to obtain 85-90% shoot control. (Table 5).

The major treatment suggested and used in North Dakota is the combination of 0.25 lb/A picloram plus 0.5-lb/A 2,4-D. This combination has resulted in 73% reduction in leafy spurge stand after 3 successive years treatment. Data are not available from 4 years retreatment.

Although there are considerable data available as to the effectiveness of the various herbicides and/or combinations toward leafy spurge shoot control, the data are quite limited on their effectiveness in reducing the root biomass. Rumors and lack of supportive data indicate little or no root reduction from herbicide treatments. Leafy spurge root assays have been one of the University of Wyoming's major emphasis. Several methods to relate shoot control to root control-have been researched starting with the resistance to pull through core sampling and hand separation to the most recent greenhouse vegetative root biomass transplants. The methods used have been extremely time consuming and laborious with correlation of shoot/root reduction difficult to measure. However, data presented in Tables 7, 8 and 9 indicate that the reduction in root biomass corresponds quite closely to the shoot reduction.

There is no doubt a concern with the cost of herbicide treatments, especially with the Tordon herbicides. One factor that has not had a figure for economic analysis attached to it, is the intrinsic value of reducing the population and continued spread of leafy spurge. Minimizing the spread can produce long-term economic benefits not yet measured. Selecting a treatment that is the most effective and will reduce or eliminate the spread may be the most economical treatment for a "total control" aspect.

Table 1. Percent shoot control original treatments.

Original Tr.	Rate lb a.e./A	79	80	81	82
Picloram Liquid	0.5	76	43	29	29
Picloram Liquid	1.0	97	94	84	78
Picloram Liquid	2.0	99	94	90	90

Table 2. Percent shoot control retreatments*.

	Retreatment					
	Rate lb a.e./A					
Original	Tordon 22K 0.5			Tordon 22K 1.0		
	80	82	84	80	82	84
Picloram Liquid 0.5	94	98	92	99	100	97
Picloram Liquid 1.0	96	99	94	99	100	98
Picloram Liquid 2.0	99	100	97	99	100	100

*1979, 80, 81

Table 3.

LEAFY SPURGE

MT, ND, SD, WY

Scattered Infestations

Isolated Patches

Inaccessible Areas

Suggested Use Rate/acre:

Spring:

Tordon*22K or Tordon*2K

2 lb a.e./A	2 lb/A
1 gal/A	100 lb/A Product

Fall:

Tordon 2K

2 lb a.e./A

100 lb/A Product

Will maintain 85-90%** shoot control for 3-4 yrs.

**Varies due to soil type, moisture, etc.

*Retreat any time shoot control drops below 75%

Retreatment Schedule

Tordon 22K 1qt/A or Tordon 2K (25 lb/A Product)

Table 4.

LEAFY SPURGE
MT, ND, SD, WY
Scattered Infestations
Isolated Patches
Accessible to Easy Retreatment
Suggested Use Rate/acre:
Spring:
Tordon*22K or Tordon*2K

1 lb a.e./A	1 lb a.e./A
2 qt./A	50 lb/A Product

Fall:
Tordon 2K
1 lb a.e./A
50 lb/A Product

Will maintain 85-90%** shoot control for 1-2 yrs.
**Varies due to soil type, moisture, etc.
*Retreat anytime shoot control drops below 75%

Retreatment Schedule
Tordon 22K 1qt/A or Tordon 2K (25 lb/A Product)

Table 5.

LEAFY SPURGE
MT, ND, SD, WY
Large Uniform Infestations
Accessible to Easy Retreatment
Suggested for rocky, shallow, low organic matter soils
Suggested Use Rate/acre:
Spring:
Tordon*22K or Tordon*2K

0.5 lb a.e./A	0.5 lb a.e./A
1 qt./A	25 lb/A Product

Fall:
Tordon 2K
0.5 lb a.e./A
25 lb/A Product

*One application will give 70%** or less shoot control one year following application
**Varies due to soil type, moisture, etc.

Retreatment Schedule
Retreat with 0.5 lb a.e./A Tordon 22K or Tordon 2K for 2-3 successive years. Will give 85-90% shoot control. Retreat when shoot control drops below 75%.

Table 6.

LEAFY SPURGE	
ND	
Large Uniform Infestations	
Accessible to Easy Retreatment	
Suggested Use Rate/acre:	
Tordon 22K	0.25 lb a.e./A
	1 pt./A
2,4-D Amine	0.5 lb a.e./A
	1 qt./A
Retreat every year. Three years of successive treatments have given 73% shoot control in North Dakota.	

Table 7. Resistance to pull and percent live roots in top 6 to 8 in. of soil

Treatment[1]	Rate Lb. a.e./A	Resistance[2] To Pull	% Live Roots 6 to 8 in.
Picloram Liquid	0.5	3.1	58.3
Picloram Liquid	1.0	0.58	0.0
Picloram Liquid	2.0	0.67	0.0
Picloram G	0.5	2.1	33.3
Picloram G	1.0	1.6	16.7
Picloram G	2.0	0.58	0.0
Dicamba	4.0	1.9	25.0
Dicamba	8.0	1.0	8.0
CHECK	–	5.0	100.0

1 Treatments Applied May 25, 1983.

2 Evaluation June 21, 1979.

0 = (No Resistance)

5 = (Unable To Pull)

Table 8. Leafy spurge root counts original and one retreatment.

Original[1] Lb. a.e./A		Retreatment Lb. a.e./A	Root Segments/Cu. Ft.[2] Soil Depth (In.) 0-8	8-16	16-24	24-32	% Control Shoot	Root
Picloram L	2.0	Check	1.7	13.8	39.5	146.1	96	92
Picloram L	2.0	0.5	24.0	13.8	27.5	51.6	99	95
Picloram L	2.0	1.0	3.4	58.4	77.4	142.6	99	87
Picloram L	1.0	Check	5.2	24.0	10.4	37.8	94	96
Picloram L	1.0	0.5	1.7	10.4	10.4	20.6	96	98
Picloram L	1.0	1.0	0.0	1.7	3.4	5.2	99	99+
Picloram G	2.0	Check	3.4	3.4	3.4	8.6	95	99+
Picloram G	2.0	0.5	0.0	24.1	24.0	22.4	98	97
Picloram G	2.0	1.0	0.0	6.9	60.2	77.4	100	93
Picloram G	1.0	Check	44.7	154.6	159.8	142.6	51	76
Picloram G	1.0	0.5	0.0	20.6	17.2	25.8	99	97
Picloram G	1.0	1.0	13.8	25.8	60.2	84.2	99	91
Check		Check	770.1	374.7	498.4	464.0		
% Root segments-Various Soil Depths			36%	18%	24%	22%		

Table 9. Vegetative root biomass transplants.

Treatments[1] Original/Retreatment Lb. a.e./A	% Shoot[2] Control (Field)	No. Shoots Per Container
Picloram L 2.0/0.5	100	0
Picloram L 2.0/1.0	100	0
Picloram L 1.0/0.5	98	0
Picloram L 1.0/1.0	100	0
Picloram 0.5/0.5	98	0
Picloram 0.5/1.0	100	0
Check /0.5	97	0
Check /1.0	100	0
Check	0	22

[1]Original Treatments 1978
Retreatments 1979, 80, 81
[2]Sampled 1983

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Economical control of leafy spurge

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The North Dakota Legislature emphasized leafy spurge control in the 1981-1983 biennium when it appropriated 500,000 dollars for a cost share program. Also, each county was allowed to increase its tax by 1 mill to be used exclusively for leafy spurge control. The funding was divided 33:47:20 between the state, county and landowner, respectively. The 1983 and 1985 Legislatures provided additional biennial appropriations of 500,000 and 600,000 dollars, respectively, to continue the cost-share program through the 1986-87 fiscal year.

There were approximately 750,000 acres in North Dakota infested with leafy spurge in 1980. The common herbicide treatment was either 2,4-D at 1.0 to 2.0 lb/A which cost $2 to 4/A and did little to control the weed or picloram at 2.0 lb/A which gave control for 2 to 3 years but cost $80/A. Thus a more cost effective, long-range program was needed to control leafy spurge on as many acres as the cost share money would allow.

It is difficult to assess the importance of leafy spurge control on long-term land values, but it is possible to estimate short-term returns by measuring changes in forage production and grazing capacity following leafy spurge control. The purpose of these studies was to evaluate several leafy spurge management alternatives with herbicides for leafy spurge control, forage production, and economic return.

Materials and methods

Forage production. An experiment to evaluate long-term leafy spurge management including forage production was established at two sites (Sheldon and Valley City) in North Dakota in 1980. The predominate grasses were bluegrass (*Poa* spp.) with occasional crested wheatgrass (*Agropyron desertorum*), smooth brome (*Bromus inermis*), big bluestem (*Andropogon gerardii*) or other native grasses. The sites were established in early June and herbicides applied included 2,4-D [(2,4-dichlorophenoxy)acetic acid) at 2.0 lb/A and picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid; tradename Tordon) at 1.0 and 2.0 lb/A. The whole plots were 15 by 150 feet and treatments were replicated twice at each site in a split plot design with a factorial arrangement of treatments. In June 1981, each whole plot was divided into six 7.5 by 50 feet subplots for retreatments of 2,4-D at 1.0 lb/A, picloram at 0.25 lb/A alone or with 2,4-D at 1.0 lb/A, and dicamba (3,6,dichloro-2-methoxybenzoic acid; tradename Banvel) at 2.0 lb/A or no retreatment, except the fall Valley City site which was retreated in August 1981.

The whole plots were retreated in 1982 with the original treatment, except picloram at 2.0 lb/A was reapplied to the control subplot only since subplots receiving annual retreatments maintained satisfactory leafy spurge control. Subplot retreatments were applied again in 1983 and 1984.

Forage yields were obtained from each plot by harvesting a 3 by 25 feet section with a flail mower in July 1981 and a 4 by 15 feet section with a rotary mower in July 1982, 1983 and 1984. Sub-samples were taken by hand along each harvested strip and separated into leafy spurge and forage so the weight of each component in the mowed sample could be calculated. The samples were oven dried at 140º F and are reported with 12% moisture content. The entire plot was mowed after harvest each year to remove dead leafy spurge stems and other plant material for improved forage measurement and maintenance of plot uniformity. Economic return was estimated by converting forage production to hay sold for $48.00/T minus the cost of the herbicide and estimated application cost, i.e. 2,4-D = $2.17/lb ai, picloram 2S = $40/lb ai, dicamba – $10.30/lb ai, and application = $2.04/A.

Forage utilization. An experiment to evaluate forage utilization by cattle in various densities of leafy spurge was established on 1 May 1984 near Leonard, ND. The 300 A pasture carried 80 cow-calf pairs from May until mid-October. Caged plots were established in four leafy spurge densities, 80% or above (high), 40-80% (moderate), 20-40% (low) and no infestation (zero). Four caged and uncaged 0.25 m^2 paired plots were established per density and there were three replications. Picloram at 1.0 lb/A was applied on 15 June to establish the zero density areas. Production was harvested on 25-26 July and 18 October for caged and uncaged plots, respectively, and separated into cool- or warm-season grasses, leafy spurge and forbs. Caged plots estimated production while the difference between caged and uncaged plots estimated utilization. Natural disappearance of forage was estimated from similar experiments to be 30%.

Herbicide synergism. An experiment to determine the number of annual applications of picloram needed to provide 90 to 100% control of leafy spurge and to investigate possible synergism between picloram and 2,4-D was established at three locations in North Dakota. The experiment was begun on 25 August 1981 at Dickinson, 1 September 1981 at Sheldon and on 11 June 1982 at Valley City. The soil at Dickinson was a loamy fine sand with pH 7.2 and 0.6% organic matter, at Sheldon was a silty clay loam with pH 5.8 and 3.4% organic matter, and at Valley City was loam with pH 6.0 and 3.3% organic matter. Dickinson, located in western North Dakota, generally receives much less precipitation than the other two sites located in eastern North Dakota. All treatments were applied annually except 2,4-D alone which was applied biannually (both spring and fall). Picloram treatments were applied in late August 1981 and in June of 1982 through 1984. Thus, the Dickinson and Sheldon sites have received four picloram and picloram plus 2,4-D treatments and seven 2,4-D treatments, while the Valley City site has received three and six treatments, respectively. The plots were 10 by 30 feet and each treatment was replicated four times in a randomized complete block design at all sites. Evaluations were based on percent stand reduction as compared to the control.

Results and discussion

Forage production. The treatments in these experiments provided the intended wide range of leafy spurge control to evaluate the impact of various treatment programs on forage production (Table 1). Annual application of 2,4-D (Treatment A) provided only 21% leafy spurge control after 5 years of treatment. Annual application of 2,4-D stopped leafy spurge seed production and restricted the infestation from enlarging, but reduction of the original infestation was small. Leafy spurge control was similar with picloram applied at 1.0 or 2.0 lb/A in 1980 and 1982 (Treatments B and F), and averaged 81%. Adding an annual herbicide retreatment to picloram at 1.0 and 2.0 lb/A (Treatments C, D, E, G, H, and I) improved leafy spurge control only 7% for spring applied treatments. Thus, when high rates of picloram were applied every other year, there was little advantage to using more than 1.0 lb/A of picloram or to applying annual retreatments. Dicamba at 2.0 lb/A (Treatment J) generally provided leafy spurge control between 2,4-D (Treatment A) and picloram at 1.0 lb/A (Treatment B).

All treatments were harvested for forage production from 1981 to 1984. Forage yield tended to increase while leafy spurge production was decreased by all herbicide treatments (Table 1). Total dry matter (forage plus leafy spurge) production tended to decrease following all herbicide treatments compared to the control, and the reduction was due mainly to leafy spurge control. However, some treatments also reduced grass production. For example, forage production averaged 1193, 1632, 1551 and 1334 lb/A for picloram at 0 (control), 0.25 (annual), and 1.0 and 2.0 (alternate years) lb/A (Treatments M, K, B, and F), respectively, while leafy spurge production was 1240, 34, 60 and 20 lb/A for the same treatments, respectively. Thus, leafy spurge control with picloram resulted in greater forage production than the untreated control. However, injury to grass, mostly non-visible, by picloram at 1.0 and 2.0 lb/A applied every other year prevented the maximum increase of forage production when compared to picloram at 0.25 lb/A applied annually.

The highest average forage production was from picloram at 2.0 lb/A followed by annual treatments of picloram at 0.25 lb/A (Treatment H) or picloram plus 2,4-D at 0.25 plus 1.0 lb/A annually applied (Treatment L) which averaged 1809 and 1793 lb/A, respectively (Table 1). 2,4-D at 1.0 lb/A provided only 21% leafy spurge control but 1787 lb/A forage production (Treatment A). 2,4-D applied annually in the spring kills leafy spurge top growth and allows for increased forage production but does little to reduce the infestation.

The only treatments that provided a positive net return were picloram at 0.25 lb/A, picloram plus 2,4-D at 0.25 Plus 1.0 lb/A, and 2,4-D alone (Treatments K, L, and A) (Table 1). A program with low picloram rates that gradually reduced the leafy spurge infestation with an annual application of a relatively inexpensive herbicide combination was more cost effective for forage production and weed control than a single high picloram rate treatment.

All treatments that included picloram at 1.0 and 2.0 lb/A or dicamba at 2.0 lb/A (Treatments B through J) either as original or retreatments provided both low leafy spurge and increased forage production compared to the control, but resulted in net losses of $32 to 147 per acre (Table 1). These losses were due to the high cost of the herbicides and/or the less than maximum forage production due to grass injury. Thus, treatments with high rates of picloram and dicamba cannot be justified directly on improved net income. However, these treatments had a comparatively long soil residual that provided the highest leafy spurge control. They can be cost-effective in a prevention program to eradicate small infestations of leafy spurge, so annual treatment of large areas will not be required in the future.

This study probably underestimates the true dollar value of a control program on land that is grazed by cattle. Cattle refuse to graze in high densities of leafy spurge and thus the annual forage production of 1193 lb/A in the untreated area of this study may not be utilized.

Cattle utilization. Forage production was similar in all densities of leafy spurge except the highest density (Table 2). Unlike many pasture and rangeland weeds, leafy spurge only reduced forage production slightly. However, the forage produced is lost if cattle refuse to graze an infested area. Cattle utilized 31 and 34% of the total forage produced in the zero and low leafy spurge density plots, respectively. Utilization declined to 21% when leafy spurge reached a moderate density of 11 stems/ft^2, and to zero utilization in the high density plots of 22 stem/ft^2. It was expected that cattle would not graze in the moderate density plots but there are several possible reasons this area was grazed. Cattle may naturally graze in moderate leafy spurge stands, but past observations indicate this is unlikely. Mid-May to October was very dry and the stocking rate (animals/area for a given time) was very high so that the cattle may have been forced to graze in more dense leafy spurge stands than normal. Also, cattle were observed grazing in leafy spurge stands after the plants were killed by frost but prior to the final harvest. Thus, utilization would have been overestimated. During the second year of the study uncaged plot areas will be harvested monthly so utilization can be estimated throughout the growing season.

Herbicide synergism. Picloram at 0.25, 0.375 and 0.5 lb/A provided 48, 52 and 81% leafy spurge control, respectively, in August 1984 after four treatments when averaged across the Dickinson and Sheldon locations (Table 3). Control had gradually increased for the picloram at 0.5-lb/A treatment, but not the 0.25 or 0.375 lb/A treatments when compared to the August 1982 and 1983 evaluations. 2,4-D alone provided between 26 and 38% control of leafy spurge after biannual applications for four years.

Leafy spurge control tended to increase when 2,4-D was applied with picloram at 0.25 or 0.375 lb/A (Table 3). Leafy spurge control in June 1985 increased an average of 27 and 8% with picloram at 0.25 or 0.375 lb/A plus 2,4-D at 1.0 to 2.0 lb/A, respectively, when compared to the same picloram rate applied alone. Picloram at 0.5 lb/A plus 2,4-D provided 80 to 82% leafy spurge control and was similar to picloram at 0.5 lb/A alone at 74%. The greatest enhancement with 2,4-D plus picloram seems to be with 2,4-D at 1.5 lb/A or less and picloram at 0.375 lb/A or less. In general, leafy spurge control was similar at all sites and did not seem to be influenced by soil types, pH, organic matter or annual precipitation. After four treatments only picloram at 0.5 lb/A, with or without 2,4-D, is within 10% of the target of 90 to 100% leafy spurge control.

Several long-term management alternatives provide a choice of herbicides, duration of acceptable control, and forage production in leafy spurge infested areas. If leafy spurge is in an area that can be treated annually with relatively low application costs, then picloram at 0.25 lb/A or picloram plus 2,4-D at 0.25 plus 1.0 lb/A should be the most cost effective treatments when considering both leafy spurge control and forage production. The leafy spurge stand can be reduced gradually while the forage production and forage utilization by cattle is maximized. If leafy spurge is located in terrain where annual application is very expensive, then picloram at 1.0 and 2.0 lb/A could be used to provide long-term leafy spurge control. The effectiveness of leafy spurge control on future land value cannot be assessed. However, leafy spurge infested land will always have a lower value than uninfested land due to reduced production and carrying capacity. It is much more economical to control small areas of leafy spurge when it first appears, rather than allow the infestation to expand.

Table 1. Leafy spurge control, annual forage and leafy spurge production, and net return with several herbicide treatments for four years in North Dakota.

Treatment 1980 and 1982	Rate	Retreatment 1981, 1983-1984	Rate	1985 Control	Annual production: Forage	Annual production: Leafy spurge	Total[a] cost	Net return
	(lb/A)		(lb/A)	(%)	(lb/A)	(lb/A)	($/A)	($/A)
Spring applied								
A. 2,4-D	2.0	2,4-D	1.0	21	1787	46	25	+ 46
B. Picloram	1.0	...	...	76	1551	60	84	- 41
C. Picloram	1.0	Dicamba	2.0	92	1497	0	152	- 115
D. Picloram	1.0	Picloram	0.25	78	1323	10	120	- 104
E. Picloram	1.0	Picloram + 2,4-D	0.25 + 1.0	92	1780	1	127	- 57
F. Picloram	2.0	...		86	1334	20	164	- 147
G. Picloram	2.0[b]	Dicamba	2.0	96	1515	0	175	- 136
H. Picloram	2.0[b]	Picloram	0.25	92	1809	0	132	- 58
I. Picloram	2.0[b]	Picloram + 2,4-D	0.25 + 1.0	88	1626	0	141	- 89
J. …	...	Dicamba[c]	2.0	72	1677	98	91	- 32
K. …	...	Picloram[c]	0.25	62	1632	34	48	+ 5
L. …	...	Picloram + 2,4-D[c]	0.25 + 1.0	70	1793	0	57	+ 15
M. Control	...	Control	...	0	1193	1240		0
LSD (0.05)				21	477	486		

[a]Costs do not include 1985 treatment cost, since forage increase will be measured by the July 1985 harvest.

[b]Retreatments were applied instead of picloram at 2.0 lb/A in 1982.

[c]Treatment applied annually 1981-1984; no treatment in 1980.

Table 2. Forage utilization by cattle in four leafy spurge densities.

Leafy spurge density	Leafy spurge	Leafy spurge	Yield						Disappearance	
			Caged			Uncaged				
			Cool	Warm	Total	Cool	Warm	Total	Total	Utilization
(% cover)	(stems/ ft)		(lb/A)						(%)	
0 (zero)	0	31	1259	159	1418	484	74	558	61	31
20-40 (low)	5	89	1517	265	1782	522	119	641	64	34
40-80 (moderate)	11	464	1061	486	1547	442	304	746	51	21
80-100 (high)	22	1362	925	245	1170	600	217	817	30	0
LSD (0.05)	3	221	396	209	440	396	209	440	4	

[a]Estimate of utilization by cattle based on: Total disappearance - natural disappearance (30%).

Table 3. Leafy spurge control from annual picloram or picloram plus 2,4-D treatments and biannual 2,4-D treatments at three locations in North Dakota.

Herbicide	Rate	Site and 1985 evaluation			Mean			
					August			June
		Sheldon	Dickinson	Valley City	1983	1983	1984[a]	1985
	(lb/A)	(% control)						
Picloram	0.25	12	61	34	39	48	48	36
Picloram	0.375	55	66	78	65	62	52	66
Picloram	0.5	87	74	58	65	71	81	74
2,4-D bian	1.0	31	44	23	22	30	38	33
2,4-D bian	1.5	35	31	38	22	24	26	35
2,4-D bian	2.0	51	29	41	19	30	26	40
Pic + 2,4-D	0.25+1.0	48	82	51	52	66	63	60
Pic + 2,4-D	0.25+1.5	72	71	48	58	66	70	63
Pic + 2,4-D	0.25+2.0	70	71	58	57	62	66	66
Pic + 2,4-D	0.375+1.0	77	82	65	69	72	70	75
Pic + 2,4-D	0.375+1.5	63	85	69	68	74	76	72
Pic + 2,4-D	0.375+2.0	90	75	64	68	59	76	76
Pic + 2,4-D	0.5+1.0	86	89	70	71	75	84	82
Pic + 2,4-D	0.5+1.5	78	85	81	64	73	80	81
Pic + 2,4-D	0.5+2.0	71	86	84	76	75	81	80
LSD (0.05)		33	23	24	18	14	19	15

[a]Experiment at Valley City began in June 1982 and is not included in August 1984 mean.

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Is there a pay-off for basic research on leafy spurge?

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Leafy spurge is a deep-rooted perennial plant that contains a white, milky latex. It can readily invade and occupy a variety of ecological niches, but is most troublesome on low value (and I use this term loosely) rangeland, pasture land, and recreational land. What I have just briefly described is the nature of leafy spurge and some of the potential problems associated with its control.

Once the problem is defined, we try to find successful and economical control solutions by chemical, cultural, and biological means. If the control measures are not successful or economical, and our attempts to find a quick, cheap, and easy control method fail, then we must change our strategy and determine why the plant survives all our attempts to kill it. This is where we must "bite the bullet" and conduct the basic science studies on the specific mechanisms which allow the plant to evade and survive control measures and also do research to discover the weak links in the plant that may be broken in some practical and economical manner. Here is where research on the physiology and biochemistry of the plant fits in.

The theme of today's session "The Pay-off for Five Years of Leafy Spurge Research." My talk, in particular, is to address the question, is there a pay-off from basic research on leafy spurge? To put the efforts on basic research of leafy spurge in context with the other areas that have been funded during the past 5 years, I have to say that the applied chemical and cultural research programs, awareness programs, and the biological control programs have received the lion's share of the funding, but nevertheless, there has been a pay-off from the basic and applied physiological and biochemical studies on the leafy spurge plant itself and the herbicidal chemicals used in an attempt to control that plant.

What are some of the things we have accomplished?

Initial field observations show that different leafy spurge biotypes have differential sensitivity to herbicides. After these observations, some laboratory studies have been conducted on the uptake, translocation, metabolism, and mode of action of the herbicides. These studies provide the type of information that will help us use the herbicides in the most effective manner possible and these studies also in a somewhat indirect fashion help us understand the physiology of the leafy spurge plants.

Based on many years of field experiments with various herbicides, Lym and Messer from NDSU published this widely used figure that depicts the sensitivity of leafy spurge to three herbicides throughout the season. Various laboratory researchers have conducted studies on the herbicides and the plants to help explain this figure. Since the bottom line on the sensitivity of leafy spurge to herbicide is "will the herbicide effect root buds?" we are doing research on the root buds to determine why they remain inactive and what biochemical changes must take place before the buds will grow and draw the lethal herbicides to them.

A unique feature of the leafy spurge plant is its white, milky latex. The latex contains massive amounts of starch, a potential food source for the plant. Past work by laboratory researchers has shown that this food source is not useable by several members of the Euphorbiacae family of which leafy spurge is a member. Scott Nissen, my research assistant, has shown that the starch in the latex of leafy spurge is apparently not used even when the plant is under light starvation conditions. Just like you and me a plant does not do something for nothing. So I pose the question then; why is leafy spurge putting so much effort and energy into the production of food that it cannot use? We don't know. My gut feeling is this could be a weak link in the plant that may be exploited and it warrants considerably more attention.

The last area I'm going to talk about today is the work Bruce Maxwell, a graduate student of Pete Fay's, began several years ago under my supervision. The fundamental reason why leafy spurge is not controlled by chemicals, and may not be successfully controlled by biological agents in the future, is that it possesses a very deep and hearty root system that has numerous buds that serve as a survival mechanism when the plant is under attack. When the plant is attacked by chemicals, sheep, or potential biological control agents, the dormant buds begin growing and re-establish the top of the plant. Hence, the infestation reoccurs and flourishes. Until we deal with and understand root bud dormancy, which is the fundamental reason for the poor control of leafy spurge, we will, in all probability, have no basis for its management. What I just said is that until we understand the problem, in all likelihood, we will not solve the problem.

Now let's move into some of Bruce Maxwell's work on root bud dormancy in leafy spurge by posing this question: "Can we make all dormant buds grow?" If we could make all dormant buds grow, we may be able to deplete the food reserve in the root and kill all the emerged shoots with some chemical or cultural treatment. The answer to the question is maybe, and here's why. Early field observations by Fay and Maxwell indicated that Roundup herbicide made the shoots of leafy spurge grow prolifically. We call this witch's brooming. Upon further observation it was discovered that the buds on the crown of the plant were released from dormancy and also were growing prolifically in response to the Roundup application. In digging deeper we found that some of the dormant buds deeper on the root system were being released from dormancy and were growing. I believe this research, in part, validates the notion that we may be able to induce leafy spurge root bud growth. Then, when all the food reserve has been used and many stems are present, we can attack the plant and dramatically increase our chance of controlling the infestation.

I have to add a word of caution. Roundup does not control leafy spurge. At present, Roundup is simply a novel laboratory chemical that can be used to study dormancy in leafy spurge. What I have just shown you has no immediate practical application in the field but it does demonstrate that the potential exists to control the plant once we have learned more about the fundamental problem associated with the plant and that problem is root bud dormancy.

I pose the next question: “Will we accomplish more in the next 5 years?” I am not going to answer this question optimistically or pessimistically. I will answer it very frankly and realistically. Each physiologist, given his or her individual talent, creativity, and hard work, will accomplish all that is possible. But sufficient money that is now not available must be provided to fund this critically important research. In essence, those that are concerned with finding control solutions for leafy spurge and that hold the purse strings will ultimately answer this question.

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Prospects for biological control of leafy spurge

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To start my discussion I would like to pose the question “Why does leafy spurge present such a difficult challenge for biological control?” As a partial answer to this question let’s compare some biological, economic, and political attributes of two other problem weeds with leafy spurge in order to fully appreciate the complex situation with leafy spurge.

Musk thistle – *Carduus nutans* L.

- annual or biennial weed
- only reproduces by seed
- no known allelochemicals
- single insect (the seed head weevil, *Rhinocyllus conicus* Froel.) plus good range management (i.e., good competing vegetation) generally adequate to control the thistle
- relatively easy plant to control biologically
- some potential conflict with native thistles, however the weevil is less successful on these plants than on musk thistle; no detrimental effects on native thistle densities have been documented

Spotted knapweed – *Centaurea maculosa* Lam.

- short lived perennial
- only reproduces by seed
- allelochemicals present
- fierce competitor
- reports of 95% seed destruction per individual flower head where both seed head flies, *Urophora affinis* (Frld.) and *U. quadrifasciata* (Meig.) occur together and in high numbers
- this level of seed destruction not adequate to demonstrably affect plant density, perhaps due to prolific seed production and seed accumulation in the soil

– complex of 4 or 5 insects plus some plant diseases may be necessary to substantially affect plant density

– probably moderately difficult to control biologically

– only 1 or 2 native plant species appear to be in potential conflict with the natural enemies we release against spotted knapweed

Leafy spurge, *Euphorbia pseudovirgata* (Shur) Soó (= *E. esula* L. x *E. virgata* Waldst. & Kit.)

– perennial

- reproduces by seed and vegetatively by underground adventitious root buds

- seeds explosively released up to 15 ft. from the parent plant

- extensive underground root system and root reserves make the weed extremely difficult to control by conventional means

- plant is genetically variable which may influence the effectiveness of chemical and biological control

- suspected of having allelochemicals (less documented than in spotted knapweed)

- will probably take a complex of 4 or 5 insects plus some plant diseases before plant density is affected

- probably will be the most difficult of the 3 weeds to control biologically

- 107 native plant species in the family Euphorbiaceae may be in potential conflict (to varying degrees) with the natural enemies that are released against leafy spurge

Conflict of interest

I would like to spend some time discussing an issue that seems to be fundamental to biological control efforts directed against most weeds. The issue is called conflict of interest and in simple terms is when a weed has both beneficial attributes as well as it causes economic damage. Some of the basic components and examples of conflict of interest are outlined below:

1. Benefits

   a. Economic

      1) Weed may produce lots of nectar and pollen and thus benefit the honeybee industry

      2) Relatives may be of economic importance:

         a) *Euphorbia lathyris* – petroleum plant

         b) Poinsettia – Christmas ornamental

b. Aesthetic/Environmental

1) Native relatives may produce pretty flowers

2) Concern for potential impact of natural enemies on native plant species, particularly those proposed for endangered species status

eg., Family Euphorbiaceae (to which leafy spurge belongs) has 113 plant species native to North America

– Four or five native species of Euphorbiaceae have apparently been proposed for endangered species status

2. Economic Damage

a. Production Losses

1) Competition for water, nutrients, and light

2) Range-animal exclusion

3) Toxic residues

4) Displacement of favorable native and introduced forage species

5) Reduction of favorable wildlife habitat

b. Control Costs

1) Fuel

2) Labor

3) Herbicide/Cultural management/Biological control costs

There is a definite need for weighing the beneficial attributes of leafy spurge against the economic damage that it causes so that rational weed management decisions can be made. Unfortunately, leafy spurge presents a special dilemma for biological control researchers. When faced with a weed such as leafy spurge, with apparent genetic variability, the natural enemies that are released against the weed should have the ability to feed on a range of genetic types of the plant. Otherwise, if the natural enemies are too restricted in their feeding they will not contribute much toward the overall control of the weed. On the other hand, when attempting to biologically control a weed such as leafy spurge with 113 native plant species in potential conflict, the natural enemies should be extremely specific in their feeding to minimize their impact on the native flora. Thus, we are caught between a proverbial rock and a hard place with this particular weed!

For such a damaging weed as leafy spurge with no apparent economically feasible means of controlling large infestations of the weed on marginal rangeland, other than biological, we may have to accept a slightly higher risk to the native plant species than with most other weeds. But, we should be cautious at the onset and exhaust the list of extremely specific natural enemies first to minimize any potential risk to the native flora. If these prove to be ineffective in controlling leafy spurge, then we might have to turn to control agents with a slightly broader host range that may offer an even greater potential for control. I hope we can some day strike a rational balance between the ecological concern for the potential impact of these natural enemies on the native flora and the economic damage caused by this weed.

Other issues that need more attention are the impact of herbicides on the native flora and the displacement of native plant species by the weed itself. A consideration of these issues plus an assessment of the possible benefits of leafy spurge vs. the economic damage it causes will help us develop a sound biological control policy/effort against this particular weed.

How may research efforts from the scientific community enhance current and future natural enemy effectiveness?

1. Population Ecology Studies

   –The knowledge gained from studying the population dynamics of weed natural enemies in the laboratory and in the field may help us enhance their survival and establishment in new release areas in the future

2. Taxonomy (Classification of organisms)

   –Cytogenetic, chemical, and morphological taxonomic studies will help identify the types of leafy spurge we have in North America

   –Taxonomic studies of the European plant material, from which the natural enemies are collected from, may help us more appropriately match up the natural enemies with the proper leafy spurge plant material in North America

3. Allelopathy/Plant Resistance

   –Finding perennial grass species that show resistance to suspected allelochemicals in leafy spurge may help add competitive or replacement vegetation for the long term management of leafy spurge

4. Integrated Weed Management Research

   –The knowledge gained from studying the impact and use of herbicides, with biological control agents should help us better time the application of herbicides to minimize their impact on weed natural enemies.

Insect quarantine – Montana State University

–Possible completion date (early 1988)

–We hope to be able to expedite the receipt and processing of insect natural enemies from Europe in the future and complement activities of the USDA Biological Control of Weeds Laboratory, Albany, CA in their efforts against leafy spurge

–Additional functions of the Insect Quarantine at MSU might be to: 1) participate in host range and specificity testing of new natural enemies, including the testing on relevant native flora; 2) free new natural enemies of their own disease and parasite problems; and 3) help in the regional rearing and redistribution of newly released natural enemies

Insects released against leafy spurge in the United States

1. *Hyles euphorbiae* – leafy spurge hawkmoth (established at two release sites in MT)
2. *Chamaesphecia empiformis* – clear-winged moth (failed to establish)
3. *Oberea erythrocephala* – stem and root boring beetle (established at two and maybe three release sites in MT; releases by N. Rees, USDA Rangeland Insect Lab., Bozeman, MT)
4. *Bayeria capitigena* – gall-forming midge (released summer 1985 in MT by R. Pemberton, USDA Biological Control of Weeds Lab., Albany, CA)
5. *Apthona flava* – flea beetle (released summer 1985 in MT by R. Pemberton)

Insects and plant diseases going through additional screening tests for potential release against leafy spurge in the U.S.

1. *Lobesia euphorbiana* – leaf-tying moth with apparently too broad a host range for consideration of release in the U.S. yet (testing conducted by USDA Biological Control of Weeds Lab., Albany, CA)
2. *Chamesphaecia* sp. – clear-winged moth that feeds on *Euphorbia virgata* with a good chance that it will attack our *E. pseudovirgata* (testing conducted by USDA Biological Control of Weeds Lab., Rome, Italy and the Commonwealth Inst. of Biological Control, Delemont, Switz.)
3. *Apthona abdominalis* – flea beetles (testing conducted by USDA Biological Control of Weeds Lab., Rome, Italy)
4. *Dasineura capsulae* – gall-forming midge (testing conducted by USDA Biological Control of Weeds Lab., Rome, Italy)
5. *Uromyces scutellatus* – systemic rust (testing conducted by Institut fur Phytomedizin, Zurich, Switz.)
6. *Oncochila simplex* – lace bug (testing conducted by USDA Biological Control of Weeds Lab., Rome, Italy)
7. *Simyra dentinosa* – moth (testing conducted by USDA Biological Control of Weeds Lab., Rome, Italy)

The most widely accepted biological approach is to release as many promising kinds of natural enemies against a weed as possible -- each adding some particular stress to the weed. It is desirable to have a full complement of natural enemies with some attacking the flowers and seeds, and others attacking the leaves, stem and root system to maximize the stress on the weed. Our ultimate hope is that this complex of natural enemies plus the effects of competition from other plant species will be sufficient to cause a decline in leafy spurge densities to economically acceptable levels.

As far as the outlook for the control of leafy spurge in the future -- I remain cautiously optimistic! The genetic variability of leafy spurge and the 113 native plant relatives in potential conflict will continue to present interesting challenges for the biological control of leafy spurge in the future. We ask for your patience. It may take 10-15 years or longer before a sufficient complex of natural enemies is established and thriving enough to cause a decline in leafy spurge density. Unfortunately, there are no guarantees of control for any weed management strategy!

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A practical and profitable way of controlling leafy spurge

DEAN A. PETERSON

Rancher, Judith Gap, MT

I am Dean A. Peterson of Judith Gap, Montana. I farm and ranch with my father (who is semi-retired). We normally run around 300 sheep, 200 cows, and farm about 1300 acres of wheat and barley. I graduated from Montana State University in 1973 with a degree in Ag. Production and Mechanics. Since 1973, 1 have worked into a major management position in the E. L. Peterson Ranch, Inc., at Judith Gap.

My father moved to our present operation from north of Havre, Montana in 1950. Havre, at that time, had no spurge problem; therefore, he had no experience with leafy spurge prior to 1950. By 1951, he realized he had a problem. Without knowing anything about leafy spurge other than that the cattle wouldn't eat it, he bought some sheep. He started out with 50 head of old ewes. It took the sheep a couple of years to start to get a handle on the spurge. After observing the economical gain of sheep on leafy spurge compared to cattle (mainly sheep would eat it, cattle wouldn't), the sheep numbers grew to around 180 head. We maintained those numbers until about 1975 when we started to increase the numbers to around 325 head. Because of the present drought, we have reduced the number of sheep from 325 down to 250 ewes and cattle from 200 down to 125 cows.

A bit of history of the leafy spurge in our area is that it was first introduced in the area by the Milwaukee Railroad when they hauled hay in for the horses to build the railroad. Along with a lack of knowledge and concern of the problem, it was spread by the two railroads, highways, and farming in the area. Since the initial infestation, it has been spread by farming and a lack of concern.

Over the past 35 years, we have learned a lot about managing sheep on leafy spurge. We have found it important to get the sheep on the leafy spurge as soon as the spring weather permits. Occasionally, we get caught in a late spring storm and are forced to bring the sheep back to the sheds. But the reason for getting them out to pasture as early as possible is that the sheep like the leafy spurge best at a young and tender stage. If we let the leafy spurge bloom, the sheep will eat it, but they do not prefer it. The sheep prefer the leafy spurge to all other forage in our pastures as long as it is in the young, pre-bloom stage. We are controlling leafy spurge with sheep by never letting it get to a bloom or seed production stage of growth. To accomplish this goal with three different pastures, we move our sheep from pasture to pasture every 2 to 3 weeks all summer. The grasses may mature by mid-summer, but the leafy spurge grows actively from freeze to freeze. After the first autumn killing freeze, we can move the sheep to fields and meadows.

Along with learning how to graze the leafy spurge, there are some other minor management problems. Apparently, the latex-type fluid in the plant, along with the continuous lush green form of the plant, makes the sheep loose (runny bowels). With this combination of latex, lush green plant, and heat of the summer, flies often produce maggots. When this problem first arose, we had a real wreck on our hands. We have since learned to control the problem by spraying the sheep for flies and tagging every 3 to 4 weeks. It is not an unmanageable problem.

We also have found that there is a management plus to grazing sheep on leafy spurge compared to non-spurge pasture. We feel we can wean lambs 10 to 15 lbs. heavier off pasture with heavy infestion of leafy spurge compared to pasture with little leafy spurge in our area.

The first and foremost plus to controlling leafy spurge with sheep is that we have halted its spread to next to nothing over the past 30 years. This has been done with an economic return from the land. Without the sheep we would essentially have wasteland with no economic value. Also, with controlling the majority of our leafy spurge with sheep, it has allowed us to attempt controlling the other lands we have with chemical.

We have chosen to control our more productive valley hay ground and farm ground with chemical. The farm ground that got out of control (more than a few spots), we have seeded to grass and control with chemical or sheep. Farming leafy spurge infested ground is absolutely the worst thing a person can do to control leafy spurge. Farming does not kill it, it spreads it. We have controlled the leafy spurge with Tordon 22K liquid and Tordon 2K pellets on the land that we have chosen not to graze with sheep. Controlling leafy spurge with chemical is a very expensive proposition. We feel it costs us, including chemical and application, around $250/acre over time to control it. At the present, we control every acre of leafy spurge we have with sheep or with chemical.

At the present, we control around 500 acres of leafy spurge with sheep (which has changed very little in the last 30 years) with an economic return from the land. Over the last 30 years, we have chosen to chemically control around 100 acres, which has been reduced to around 50 acres of spots at a cost of about $250/acre with about 50% of the original 100 acres controlled.

Sheep have been the salvation to our leafy spurge problem. Without sheep to economically or profitably control leafy spurge, we would essentially have useless land. The only alternative of controlling leafy spurge with sheep was, and still is, chemical control. The extreme cost of this chemical control was and still is prohibitive. In other words, we cannot economically justify the kind of expense it would take to control leafy spurge with chemical on the number of acres we have infested by leafy spurge.

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Chemical control group discussion

TOM WHITSEN

A concern was expressed that leafy spurge acreages were not being reduced but only being thinned. Wyoming Weed and Pest Director Cory Baker felt that we were not making progress as rapidly as should be but had only a control program. Harold Alley felt that because leafy spurge spreads at the rate of 25% yearly that control should be thought of as a spread prevention.

Concern was expressed that weed districts are sometimes held liable in potato and other susceptible plants.

Educational coordinated efforts are important in spurge control.

Knapweed spread is much faster than spurge; therefore, wildlife people are becoming more concerned because of this loss in habitat.

Biggest problem with chemical applicators is the high cost of insurance.

Programs should be redirected to the public toward consumer concerns other than just ag. producers. Need public films on "Weeds are a Growing Concern" such as Idaho has.

How will leafy spurge become eradicated? Could be chemical, biological, or genetic engineering. Sheep control could be helpful. More research is needed. One eradication technique will probably not solve the problem alone.

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Plant physiology group discussion

MICHAEL E. FOLEY

The status of the physiological research in the effort to combat leafy spurge was discussed. Physiological research has been largely overlooked and underfunded. Chemical and biological strategies may fail because we do not understand the fundamental aspects of this plant's growth and development. It was questioned whether the substantial funding for the biological control program in lieu of physiological research is putting the "cart before the horse."

Some funding for physiological research has come from USDA Cooperative Agreements. These type of funds have expired and there is little hope for their continuance. State funding should be sought but there is little hope for expansion in this area. A point was brought up that perhaps we can try harder to make the study of leafy spurge a scientific problem and look for USDA cooperative grant or even NSF monies. These grants however, are extremely difficult to get.

We must continue to focus on the root and crown buds, latex starch, and photo/thermal dormancy research. A new aspect brought up by a member of the group is perhaps the latex of leafy spurge contains symbiotic organisms, as does the latex of milkweed. Can the symbiotics be engineered to damage the plant?

The group adjourned with no resolution to our low funding problems.

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Evaluation of dicamba formulations for leafy spurge shoot control

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Wyoming Agric. Exp. Sta., Laramie, WY 82071, SR 1382.

An experiment was conducted to compare liquid and granular formulations of dicamba for leafy spurge shoot control. Plots were established June 16, 1982, south of Hulett, Wyoming along the Belle Fourche River. Treatments were applied to a dense stand of leafy spurge at bud to full bloom and 12-18 inches tall. Liquid formulations were applied with a 6-nozzle knapsack spray unit delivering 40 gpa water. Granular formulations were applied with a hand operated centrifugal broadcaster. Plots were 9 by 30 ft arranged in a randomized complete block design with three replications. Soil was a loam (38% sand, 47% silt, and 15% clay) with 1.8% organic matter and a 7.8 pH.

Leafy spurge shoot control has declined since 1983 with all dicamba treatments. However, dicamba 4DMA + X-77 at 8.0 lb ai/A and dicamba 5G at 4.0 lb ai/A are maintaining 78 and 70 percent control, respectively, three years after treatment application. Picloram 2% pellets at 2.0 lb ai/A continue to maintain excellent control three years after application.

Leafy spurge shoot control.

Treatment[1]	Rate lb ai/A	Percent[2] shoot control 1983	1984	1985
dicamba pellets 10%	6.0	95	49	33
dicamba pellets 10%	8.0	92	70	55
dicamba 4DMA + X-77	6.0	83	67	47
dicamba 4DMA + X-77	8.0	98	82	78
dicamba 4DMA + 2,4-DLVE + X-77	4.0 + 0.5	97	73	55
dicamba pellets 10%	5.0	49	51	23
dicamba pellets 10%	8.0	96	70	37
dicamba pellets 5%	4.0	94	91	70
dicamba pellets 5%	8.0	93	78	33
dicamba pellets 20%	4.0	65	68	37
dicamba pellets 20%	8.0	95	91	40
picloram pellets 2%	2.0	100	100	99

[1]Treatments applied June 16, 1982, X-77 added at 0.125% v/v

[2]Shoot counts May 18, 1983, May 23, 1984, and May 30, 1985

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Evaluation of spring vs. fall original/ retreatment combinations as affecting leafy spurge live shoot regrowth

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This experiment located near Lander, Wyoming was established for accumulation of original/retreatment and fall vs. spring application data. Five successive years of data have been collected since the experiment was established in the spring of 1980.

Original treatments were made May 23 and September 14, 1980. Liquid formulations were applied with a 13-nozzle truck mounted spray unit delivering 25 gpa water. The granular formulations were applied with a hand operated centrifugal granular spreader. Retreatments were made May 29 and September 12, 1981; May 24 and September 17, 1982; May 29 and September 15, 1983; and May 31 and September 18, 1984. The retreatments of picloram at 0.5 and 1.0 lb ai/A were terminated with the 1981 treatment. The leafy spurge was in bud to flowering stage-of-growth and 4 to 18 inches in height during the spring retreatments and had shed most of its seed when fall retreatments were made. Plots were 22.5 by 22.5 ft arranged in a split block design with two replications. Soil was a sandy loam (73% sand, 15% silt, and 12% clay) with 1.3% organic matter and 7.6 pH.

The area has been flood irrigated following application of original treatments. There was thin grass cover when plots were established. By September 1981 grass was 20 to 24 inches in height and green in treated areas. Good grass cover has been maintained in treated areas since 1981.

Percent shoot control is based on reduction of live leafy spurge shoots in treated plots as compared to the untreated (check) plots.

The picloram original treatment at 2.0 lb ai/A provided the most effective long-term leafy spurge shoot control. The picloram original treatment at 1.0 lb ai/A was more effective for long-term leafy spurge shoot control than was the original dicamba treatment at 4.0 or 8.0 lb ai/A. Retreatments have been more effective for controlling leafy spurge shoot growth than a one time single treatment. There has been a reduction in shoot control in the picloram retreatment plots since the retreatments were terminated with the 1981 application. However, picloram retreatments have generally been the most effective followed by dicamba, 2,4-D (S & F) and 2,4-D. Leafy spurge shoot control has decreased in most of the original treatment plots over the last five years, however, there seems to be little difference in the effectiveness of the original treatments whether spring or fall applied.

Leafy spurge shoot control.

Original[1] lb ai/A		Percent Shoot Control[2] — Retreatment lb ai/A																								
		dicamba 4L 2.0				picloram (K salt) 0.5				2,4-D amine (S&F) 2.0				check					picloram (K salt) 1.0				2, 4-D amine 2.0			
(Spring)		'82	'83	'84	'85	'82	'83	'84	'85	'82	'83	'84	'85	'81	'82	'83	'84	'85	'82	'83	'84	'85	'82	'83	'84	'85
dicamba 4L	6.0	94	85	89	87	100	91	85	91	88	95	93	96	92	64	29	60	56	100	99	96	83	80	70	69	78
dicamba 4L	8.0	88	90	89	85	100	95	95	94	99	100	100	100	95	81	34	26	41	99	82	75	66	90	78	63	91
dicamba 5G	6.0	89	69	81	83	100	95	80	92	87	98	97	97	92	73	86	34	44	100	100	87	58	99	97	83	90
dicamba 5G	8.0	92	73	92	93	100	94	93	96	100	99	94	97	95	89	75	32	41	100	89	79	81	93	94	94	96
picloram (K salt)	1.0	97	74	93	96	100	97	85	89	99	100	96	95	96	98	80	84	80	100	77	92	59	100	96	89	95
picloram (K salt)	2.0	100	79	96	93	100	100	96	96	100	100	100	100	99	100	91	88	81	100	75	67	66	100	94	99	99
picloram (2% beads)	1.0	98	67	93	96	100	68	85	82	93	84	88	94	93	79	95	74	71	100	81	18	18	100	89	89	98
picloram (2% beads)	2.0	100	69	89	90	100	77	86	88	100	88	97	99	95	100	93	78	83	100	24	15	0	100	95	95	98
Check	---	92	91	89	89	100	83	56	81	93	54	50	93	0	0	0	0	0	100	100	99	98	55	33	14	46
shoots/sq. ft														*20*	*18*	*17*	*11*	*12*								
(Fall)																										
dicamba 4L	6.0	76	81	75	78	100	94	81	76	90	99	92	97	70	57	61	40	51	100	93	83	81	82	70	55	84
dicamba 4L	8.0	87	88	80	93	100	92	86	77	90	95	87	98	83	44	50	44	42	100	95	83	94	89	68	67	85
dicamba 5G	6.0	99	81	91	91	100	90	81	73	97	98	98	99	89	52	39	17	52	100	97	90	98	98	79	95	95
dicamba 5G	8.0	99	93	92	97	100	93	87	89	98	98	97	98	93	85	61	30	57	100	100	99	99	97	84	71	85
picloram (K salt)	1.0	99	87	89	95	100	92	83	91	99	99	99	99	95	90	81	64	73	100	99	95	96	96	74	56	86
picloram (K salt)	2.0	100	96	97	99	100	97	93	94	100	100	100	99	99	99	93	79	79	100	100	100	99	99	93	92	94
picloram (2% beads)	1.0	100	91	98	96	100	96	83	86	100	100	99	98	99	100	96	88	88	100	97	89	87	100	86	96	95
picloram (2% beads)	2.0	100	86	95	99	100	86	73	81	100	100	100	99	99	100	94	88	82	100	91	66	84	100	85	95	86
Check	---	70	67	69	75	100	85	82	84	23	57	72	86	0	0	0	0	0	100	97	82	89	0	31	31	51
shoots/sq ft														*19*	*24*	*23*	*15*	*30*								

[1]Original treatments made May 23 and Sept. 14, 1980; retreatments made May 29 & Sept. 12, 1981; May 24 and Sept. 17, 1982; May 29 and Sept. 15, 1983; and May 31 and Sept. 18, 1984. The retreatments of picloram (K salt) at 0.5 and 1.0 lb. ai/A were terminated with the 1981 retreatment.
[2]Shoot counts May 27, 1981; May 24, 1982; May 29, 1983; May 30, 1984; and May 21, 1985. S & F = Spring and Fall.

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Procedures for the successful regeneration of leafy spurge

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Tissue culture systems were used to study the process of organ formation in leafy spurge. The intent is to try to standardize conditions that will result in plant formation from individual cells or cell clumps, and then to apply an environmental or chemical stress on the system. The cells are monitored for the formation of roots and/or shoots. If physiological processes involved in organ formation are found that are unique to leafy spurge, and if they can be interfered with by chemical or biological methods, the control of the weed might be accomplished.

Plants have been regenerated from cell suspensions in one of seven accessions of leafy spurge. Plants have been transferred from the tissue cultures to the greenhouse, and the plants look similar to the parent plant. Externally applied plant growth regulators altered growth patterns, but not in any consistent way. The cell suspensions grow actively in the presence of 2,4-D. Regeneration occurs if the 2,4-D is removed and the cells are washed free of old media and maintained in hormone-free media. The responses in various experiments differ dramatically, and to date no medium or growth condition has proved consistent with reliable and reproducible results, but several specific conditions appear to work most of the time. White light (cool white fluorescent) generally enhances root and shoot formation, and filtered light (transmission maxima of 450 or 650 nm) often increases root formation. From 50 to 67% of the inorganic nitrogen should be supplied as nitrate and about 13-millimolar potassium usually work well. The total nitrogen can vary considerably. Eighteen to 27 mM works well, although 60 mM can also be used.

Regenerated plants growing on agar or in liquid in flasks contain some epicuticular wax platelets. Cells from both organized and unorganized tissues contain large amounts of densely stained material within the vacuoles. Large numbers of microbodies with well-formed crystals are present in young plantlets developed from liquid cultures.

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Controlling spurge using all-terrain vehicles

DOUG JOHNSON

Weed Supervisor Great Falls, MT

I'm going to run through these slides quickly and try to get us back on the schedule. I'll have one of these ATV's out on the stations today and we can answer some questions then.

As you all know, we've all run into situations of trying to control leafy spurge where we've used a truck where a truck was never meant to be. Back about 1969 we thought we needed a vehicle that we can take anywhere to spray weeds and mosquitoes and started looking for the perfect vehicle. We thought an air application vehicle would work but we soon found that there's many places where we had patches of spurge on hillsides and so forth, and there were too many trees and too much brush. We just couldn't use a helicopter. We had to find something else. We started looking at commercially available all-terrain vehicles, and this is one that came out in 1969. This was a 6-wheeled outfit with a chain drive and a motor, and we fabricated a little granular spreader and thought we've got it. We'll run this through the mud and up and down the hills. Unfortunately, we didn't get may spurge plants taken care of, but we sure learned a lot about the inside of that vehicle. We spent a lot of time underneath the hood.

We started looking around to see what else was available. And some of the shows had 4-wheel drive vehicles such as this one. Well, we finally decided we'd try a tractor. We thought we would put our granule spreader on it, and started running it through the mud spraying mosquitoes. We didn't use it too much for weed control then, but we soon found we had the same problem. We were spending more time working on it. If we'd have taken the mechanics up and just have them take care of the mosquitoes we'd have saved money in the long run. We then started looking at the "Cadillacs" of the ATVs. They cost more than we could afford. They cost more than the price of a pickup; I think the same unit's probably about $30,000 today. We decided we couldn't afford that so we gave up on the ATVs for a while. We thought we did not need an all-terrain vehicle that bad.

You all know the popularity of the ATCs (all-terrain cycle). They are the 3-wheelers. We looked at them and talked to some people, tried them, and gave them a shot. We weren't real excited. Then came the 4-wheeler. We thought well, let's see what we can do with this. So we have purchased one and you can equip these with all kinds of commercially made sprayers and probably 10 companies now building these sprayers, to put little booms and hand guns and so forth on them. And they can be used in a lot of areas where you can't get a pickup truck. This one pictured is equipped with a calculator so you can determine your acreage and keep pretty close track of what you're doing. They're real easy to operate. You can use them on many terrains. You can use them down by the river in the trees; everybody knows you can't get a pickup between those trees, but you can get one of these to go snaking through the brush or whatever, you can get to the areas. I'm really going to talk about side hills and slopes today. This is a slope we did a little spraying on for a demonstration right out of Great Falls. This is the degree of a slope that you can treat with one of these if you do it right. If you get to a steeper slope, you always have to go downhill. This will probably be the maximum amount of slope you would want to handle with one of these units, equipped as this one is now. You have to go downhill, you cannot go uphill with this. You'll see the boom dragging in this particular instance. You lose traction, run out of power, and possibly injure the operator. So we're going to limit it to this gradual hillside and you can see a few spots of spurge down through here. We're going to take you through an application.

The operator starts off at the top. He is going to treat a few plants scattered here and there. Going downhill is no problem. We thought we would see how it operates on the side hills. We could run back and forth on that side hill real easy. Again, looking down; this is pretty steep slope. You can't really appreciate it from the slide. These 4-wheelers or 3-wheelers you've got to respect them. Use the gas carefully and the brake carefully. Otherwise, they can spring up and get you real quick. They're a great tool, but you've got to respect them. This could easily result, had it not been an experienced operator, a mishap to the operator. You just don't put anybody on it and turn them loose. You can do a lot of hillside work, but I would still recommend trying to run up and down. Don't side hill unless you've used the machine for a long time and know its capabilities because it's just dangerous; you're asking for problems. Again, here you see it comes right up the hill, no problem, until you hit the hole at the top.

An advantage of the 3-wheeler over the 4-wheeler stability. As you can see, it's pretty stable going downhill, it has no problem going down through this wash. The operator does not try to climb up the other side. Being an experienced operator, he simply stops the machine, gets out the handgun, and treats this wash with the handgun. If it takes two or three tanks, it's still a very efficient method of treating these small spots on the hillsides. Coming out of the wash, if you use too much gas, and don't know what you're doing, you can get into a situation like this. This was staged, this guy's a very good operator and knows exactly how to handle his machine. Just let off from the throttle and you can recover nicely. But again, if you are inexperienced, you've got to respect this machine. You can make added a little weight to correct the problem. It doesn't take much to hold that front-end down. A thick flat rock and some tarp straps makes all the difference in the world. Should you get in a steep area and you're experienced in operating, you can put your weight forward and go right up the hill. But again, you have to be careful, and you have to know what you're doing. You don't do these kind of slopes the first day you acquire a machine.

There are two things that will get you into trouble faster than anything. That's the misuse of the brakes and the throttle on these units. Lock up one or the other brakes and you're in trouble. Take your time, move slowly, and use the brakes properly you'll have no problem. On 4-wheelers, you don't want to throw your legs out. Because your leg gets caught and you come right over the top. All you have to do is sit and let the machine back down the hill; they're really stable. You've got to keep your feet on the pegs or on the machine.

I’ll talk a bit about some of the equipment and some of the things this particular unit of ours has. The other one you’re looking at belongs to Dow Chemical. We’re going to a low profile system. If you’re thinking about application of liquid, get a small tank and mount it low. This is a 10-gallon tank and you can see the little electric pump that will be mounted on it. It will sit nice and low to keep the weight low. We’ve also decided to license our unit so we can use it also for mosquito control in some irrigated areas. We want to be able to run it from place to place. This particularly 4-wheel drive, as you’ll notice, has a differential. It drives well on asphalt, the tires don’t skid and it’s easy to handle. We’ve put a county plate on it, and we had to put a brake light on it, a rear view mirror, and now we’re street legal, so we can run it down the highway from place to place. If you’re looking at small subdivision spraying leafy spurge, this will be real handy, too. You can just run down the road and go from one place to the other.

Also, another thing we have talked about is the ballast on the front. We’re going to put a tank on the front of ours as well as on the rear, and then use the liquid in the tanks at the same time to keep the weight pretty well balanced.

Here’s another use. Carrying granules to walking applicator. You can even use the unit to pull hoses.

The units are easily transported. We use a little tilt-bed trailer, but they’ll go in the back of a truck real nice, too. With ours we’re going to go to a slide-out ramp system and haul it in a pickup. We’ve had the tilt bed trailer before, and they just ended up being a lot of maintenance. We were always jack-knifing the trailer and breaking the tongue and so forth. So we’re going to stay with a pickup unit with ours.

That’s basically all I have to say. We will have that thing set up out there today at another station on the tour and not the machine you saw in the pictures, the red one, but one real similar to that. We’ll be glad to let you take a look at it and answer any questions and maybe you might take a spin on it if you’re interested. We’ll try to answer any questions.

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Leafy spurge shoot control with 2% and 10% picloram pellets

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Wyoming Agric. Exp. Sta., Laramie, WY 82071, SR 1381

This experiment was established to evaluate several picloram formulations for control of leafy spurge and was conducted at Afton and Lander, Wyoming.

The Lander plots were established June 1, 1984 on a dense stand of leafy spurge. Leafy spurge at treatment was in the seedling to full bloom stage-of-growth, 2 to 18 inches in height. The Afton plots were established August 8, 1984 on a dense stand of leafy spurge. Leafy spurge was in the prebud stage-of-growth and 6 to 8 inches in height. The granular formulations were applied with a centrifugal applicator. Plots at both sites were 9 by 30 feet. The Lander study consisted of two replications and the Afton study consisted of three replications. The soil at Lander was a sandy clay loam (54% sand, 29% silt, and 17% clay) with 1.9% organic matter and 8.0 pH, and the soil at Afton was a silt loam (22% sand, 54% silt, and 24% clay) with 3.7% organic matter and 6.2 pH.

Shoot counts were taken May 2, 1985 at Lander and a visual estimate of shoot control was taken July 11, 1985 at Afton. Percent shoot control with each treatment was similar between the two sites. However, the picloram 2% pellets gave better shoot control than the 10% pellets at both sites, for all rates. The reduced leafy spurge shoot control with the 10% pellets suggests this material is not providing as uniform distribution as the 2% pellets.

Leafy spurge shoot control.

Treatment	Rate lb ai/A	Percent shoot control[2]	
		Lander	Afton
picloram 2K	0.5	62	60
picloram 2K	1.0	84	90
picloram 2K	2.0	100	93
picloram 10K	0.5	39	50
picloram 10K	1.0	73	73
picloram 10K	2.0	80	88
Check	---	0	0

[1]Treatments applied June 1, 1984 - Lander and August 28, 1984 - Afton.
[2]Shoot counts May 2, 1985 - Lander and visual shoot control evaluation July 11, 1985 - Afton.

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Leafy spurge shoot control resulting from original and successive herbicide treatments

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No single herbicide application has been successful in total control of leafy spurge after it has become established. In 1978, a study was established to determine how long single herbicide treatments would last and what successive treatments would be required to maintain adequate control. The experiment was established May 25, 1978 with yearly retreatments. Plots 21.5 ft by 21.5 ft were arranged in a split block with two replications. Herbicides were applied with a truck-mounted sprayer in a 20-gal/A water. The soil was a sandy loam with 65.4% sand, 23.2% silt, 11.4% clay, 1.5% organic matter, and a 7.7 pH.

Weed control counts were used to determine percent control of each treatment. When no retreatments were applied to the original treatments control averaged only 15.0% across all treatments. The highest level of control was approximately 32% obtained in areas treated with dicamba at 4.0 and 8.0 lb ai/A and picloram 22k at 1.0 lb ai/A. The picloram retreatments were the most effective leafy spurge control in this study, providing averages of over 94%.

Percentage leafy spurge shoot control resulting from the original and successive herbicide retreatments, 1984, 1985.

Original Treatments[1] lb ai/A	Percent Shoot Control[2] Retreatment lb ai/A: 2, 4-D amine 2.0		Tordon 22K 0.5		Tordon 22K 1.0		Banvel 4L 2.0		Banvel/2,4-D amine 1.0 + 2.0		Check	
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985
picloram 2.0	94	87	97	99	99	99	92	88	87	77	18	16
picloram 1.0	84	76	94	96	98	100	78	75	71	73	64	32
picloram 2.0	73	63	92	97	97	99	72	65	55	49	4	20
picloram 2.0	90	86	92	98	100	100	92	79	81	69	6	2
picloram 1.0	81	59	96	98	99	100	79	70	53	50	53	17
picloram 0.5	69	53	95	98	100	100	48	53	58	54	41	21
picloram + 2,4-D amine 2.0 - 4.0	75	62	95	98	100	100	79	70	74	58	44	41
picloram + 2,4-D amine 1.0 + 2.0	73	56	93	99	100	100	65	66	50	36	12	0
picloram + 2,4-D amine 0.5 + 1.0	63	43	91	99	99	100	71	43	78	58	0	0
dicamba 8.0	75	76	74	95	98	95	91	83	70	67	34	32
dicamba 4.0	61	77	87	94	98	99	64	72	75	67	2	27
Check	78	56	95	97	98	100	82	75	47	46	--	0

[1]Original treatments May 25, 1978; retreatments yearly; except Tordon 22K terminated with 1981 treatment.

[2]Evaluations were based on quadrat counts used to determine percent control; evaluations were made May 22, 1984 and May 29, 1985.

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Project 2327: Biological control of leafy spurge

DR. LARRY LITTLEFIELD, 1982 - May 1985.
DR. ROBERT HOSFORD, June 1985 - Nov. 1985

Major accomplishments

The rust, *Uromyces striatus* was detected killing leafy spurge in southeastern North Dakota in 1982. It spread slowly from plant to plant through 1982-84. In 1985 it spread quickly by aerial spores over 3 acres of spurge. In 1985 its ureospores were found on alfalfa in the fields, then produced in the greenhouse and stored in liquid nitrogen. We are seeking ways to assist this rust in killing spurge while minimizing its affect on alfalfa.

In September 1985 we discovered a disease killing the inflorescence and then the stem of *Euphorbia esula* (leafy-spurge) in low to high numbers of plants in scattered patches to solid stands of over 100 acres in western North Dakota, central Montana and southern Oregon. We have isolated a white to pink mycelium from the diseased tissues and bacteria, and are preparing pathogenicity tests. We are also isolating fungi from purple and brown leaf and stem spots from numerous sites.

Melampsora rust spp. occur on *Euphorbia* spp. and are highly specific for their hosts. This combined with their urediospore on *Euphorbia* spp. makes them good candidates for biocontrol of leafy spurge. *Melampsora euphorbiae* was collected at Victoria, B.C. by Dr. Littlefield in August, 1984 and sent to the Plant Disease Research Laboratory (PDRL) at Frederic, Maryland. *Uromyces euphorbiae* was collected by Dr. Littlefield on a collecting trip to Eastern Europe in the spring of 1984, and that rust was also sent to PDRL. Evaluation of these rusts for host range, prior to release to us, is in progress. In September 1985 we found a *Melampsora euphorbiae* like rust on *E. esula* collected in Medford, Oregon in 1964 at the herbarium at Oregon State University (O.S.U.).

The county weed specialists at Medord (including the retired collector of 1964) are searching for the rust to send it to us. We found an unknown fungus killing the stems of *E. esula* at the base in specimens from Quebec, Canada in the herbaria at O.S.U. and at Washington State University.

During the summer of 1984, field inoculations with greenhouse effective *Alternaria tenussima* f. sp. *Euphorbiae* were made onto leafy spurge. At the three field sites (two North Dakota and one Montana) only a few inoculated plants were infected, and leafy spurge growth as measured by dry weight was not reduced significantly, compared to checks. Moisture appears to be inadequate for severe disease. In 1985 severe leaf spotting of *E. esula* in the greenhouse with *Alternaira tenussima* f. sp. *euphorbiae* was perfected.

To overcome the problem of applying alternaria during periods of inadequate moisture an approach using pellets have been initiated. Sodium alginate-pellets (Weed Sci. 31:333-338) containing alternaria have been prepared in our laboratory. In the greenhouse and field this winter and next summer the pellets will be scattered among the spurge. It is hoped that the fungus will survive in the pellets and during periods of adequate moisture spores that will infect spurge will be produced from the mycelium in the pellets.

Dr. Littlefield obtained *Sclerotium rolfsii* isolates from other parts of the country. Inoculum is being prepared for greenhouse testing of its ability to rot leafy spurge in the winter of 1985. It is assumed that this fungus will not survive North Dakota winters. Since it damages many crop plants this must be checked carefully. In 1986 we plan to look for new diseases attacking leafy spurge where it has advanced through northern North Dakota, northern Montana, Saskatchewan, Alberta, British Columbia and western Washington. In our long range planning we are looking for diseases that will minimize leafy spurge year after year and not damage other plants useful to man.

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Leafy spurge control with chemical and mechanical treatments at the Dickinson Experiment Station

LLEWELLYN MANSKE and PHILLIP SJURSEN

Two separate studies that test effects of selected treatments on leafy spurge (*Euphorbia esula*) in western North Dakota have been conducted at the Dickinson Experiment Station, N.D.S.U., since 1983.

One study tests the effects of tebuthiuron (Graslan) at three rates, 1, 2, and 3 pounds of active ingredient per acre with 20% concentration pellets. One set of replicated plots have been monitored for 3 years following treatment and a second set for two years. A control of no treatment was included in each replication.

The second study tests the effects of mowing at two different phenological stages and picloram (Tordon) at three phenological stages at 2 lbs ai per acre of 2K granules. The treatments were: at pre-flower (early June), mowing, mowing plus picloram, and picloram; post flower (seed development (early July)), mowing, mowing plus picloram, and picloram; and early regrowth (mid August), picloram. A treatment of mowing at pre-flower and a removing at post flower was included. A control of no treatment was included in each replication.

The data that was collected on all of the plots were: above ground herbage production separated into spurge, grass, forbs, and shrubs; leafy spurge stem densities separated into seedling, mature, regrowth, and dead above ground; and mean weight per leafy spurge stem. All of these data were collected on a monthly basis.

An annual report for the 1985 data will be completed prior to 31 March 1986. A summary report is planned for each study.

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Leafy spurge control with resulting forage production from several herbicide treatments[1]

RODNEY G. LYM and CALVIN G. MESSERSMITH

An experiment to evaluate long-term leafy spurge control and forage production was established at two sites in North Dakota in 1983. The predominate grasses were bluegrass (*Poa*. spp.) with occasional crested wheatgrass, smooth brome, big bluestem or other native grasses. The treatments were selected based on previous research conducted at North Dakota State University and included 2,4-D at 2.0 lb/A, picloram + 2,4-D at 0.25 + 1.0 lb/A, picloram at 2.0 lb/A and dicamba at 8.0 lb/A and were applied in August 1983 or June 1984 as spring or fall treatments. The 2,4-D at 2.0 lb/A and picloram plus 2,4-D treatments were applied annually while the picloram alone and dicamba treatments were reapplied when leafy spurge control declined to 70% or less. Thus, picloram at 2.0 lb/A was reapplied at Valley City in August of 1985 but not at Dickinson and no spring picloram retreatment was needed at either site. Dicamba at 8.0 lb/A was reapplied in June 1985 at both locations but only at Dickinson in September 1985. The plots were 15 by 50 ft with four replications in a randomized complete block design at each site. Forage yields were obtained by harvesting a 4 by 25 ft section with a rotary mower in July 1984 and 1985. Sub-samples were taken by hand along each harvested strip and separated into leafy spurge and forage so the weight of each component in the mowed sample could be calculated. The samples were oven dried and are reported with 12% moisture content. Economic return was estimated by converting forage production to animal unit days (AUD) and then to pounds of beef at $0.60/lb minus the cost of the herbicide and estimated application cost, i.e. 2,4-D = $2.00/lb ai, dicamba = $11.75/lb ai, picloram = $40.00/lb ai, and application = $2.05/A.

All herbicide treatments have resulted in an economic loss at Dickinson despite excellent leafy spurge control from several treatments. This site generally receives 8 to 10 inches less rainfall than the Valley City location. Forage production averaged across all treatments was 909 lb/A at Dickinson and 2806 lb/A at Valley City (Table). Leafy spurge control from 2,4-D at 2.0 lb/A was not satisfactory from spring or fall applications at either site. However, it did provide short-term control resulting in an economic gain at Valley City of $21 and $8/A as a spring and fall applied treatment, respectively. Leafy spurge control with picloram + 2,4-D at 0.25 + 1.0 lb/A averaged over both locations was 94% after two applications as a spring applied treatment, but only 2% when fall applied. Previous research at North Dakota State University has shown that annual application of

[1] Cooperative investigation Dep. of Agron. and ARS, U.S. Dep. of Agric. Published with the approval of the Agric. Exp. Stn., North Dakota State Univ., Fargo.

this treatment in the spring or fall provides similar leafy spurge control. Leafy spurge was under drought stress in 1984 when the herbicides were applied which may have reduced the observed control. Forage production averaged for both locations was 2036 and 1713 lb/A for spring or fall application of picloram + 2,4-D at 0.25 + 1.0 lb/A, respectively.

Picloram at 2.0 lb/A provided 87% leafy spurge control as a spring applied treatment, but only 34% control when fall applied at Valley City. However, at Dickinson control was 36 and 85% when spring and fall applied, respectively (Table). Dicamba generally gave good leafy spurge control as a fall but not as a spring-applied treatment. All treatments have reduced leafy spurge production compared to the control except the fall application of 2,4-D at 2.0 lb/A at Valley City.

Table. Leafy spurge control, forage production and estimated net return from several herbicide treatments at two sites in North Dakota. (Lym and Messersmith).

	Herbicide					Control		Yield[a]			
Original	Rate	Re-treatment	Rate	Total cost	June	Aug	Forage	Leafy spurge	Utiliz-ation	Net return
	(lb/A)		(lb/A)	($/A)	---- (%)----		-----(lb/A)-----		(AUD)	($/A)
					Valley City					
Spring 1983										
2,4-D	2.0	2,4-D	2.0[b]	12.10	0	25	2180	1718	55	21
Picloram+2,4-D	0.25+1.0	Picloram	0.25+1.0[b]	28.10	24	92	2920	1273	73	16
Picloram	2.0	...	...	82.05	99	87	3250	1228	81	- 33
Dicamba	8.0	Dicamba	8.0	192.10	53	24	2949	1178	74	-148
Fall 1983										
2,4-D	2.0	2,4-D	2.0[b]	18.15	10	0	1712	2235	43	8
Picloram+2,4-D	0.25+1.0	Picloram+2,4-D	0.25+1.0[b]	42.15	60	4	2608	1651	65	- 3
Picloram	2.0	Picloram	2.0[c]	164.10	84	36	3722	247	93	-108
Dicamba	8.0	...	...	96.05	99	87	3128	612	78	- 49
		Control					2785	2429	0	
LSD (0.05)					20	18	380	363		
					Dickinson					
Spring 1983										
2.4-D	2.0	2,4-D	2.0[b]	18.15	3	25	624	127	16	- 2
Picloram+2,4-D	0.25+1.0	Picloram	0.25+1.0[b]	42.15	23	96	1152	66	29	- 11
Picloram	2.0	...	...	82.05	89	34	1106	68	28	- 65
Dicamba	8.0	Dicamba	8.0[c]	192.10	23	30	749	76	11	- 89
Fall 1983										
2,4-D	2.0	2,4-D	2.0[b]	12.10	5	0	917	385	23	- 4
Picloram+2,4-D	0.25+1.0	Picloram+2,4-D	0.25+1.0[b]	28.05	30	0	819	421	21	- 30
Picloram	2.0	Picloram	2.0[c]	82.05	99	85	1116	4	28	- 65
Dicamba	8.0	Dicamba	8.0[c]	96.05	97	48	916	50	23	-178
		Control			0	0	779	778	0	
LSD (0-05)					11	14	280	173		

[a]Total production of 1984 and 1985 harvest.
[b]Annual retreatment.
[c]Applied when control is less than 70%.

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Leafy spurge control following a six-year management program[1]

RODNEY G. LYM and CALVIN G. MESSERSMITH

An experiment to evaluate long-term leafy spurge management was established at four sites (Sheyenne National Grassland near McLeod, Sheldon and two near Valley, City) in North Dakota in 1980. All sites were established in early June except one site, which was established in September 1980. The herbicides applied in 1980 included 2,4-D and picloram as liquid (2S) and-granule (2%G) formulations, and picloram applied using the roller and pipe-wick applicators. The conventional broadcast treatments were applied using a tractor-mounted sprayer delivering 8 gpa water at 35 psi. A granular applicator was used to apply the picloram 2%G treatments. Solution concentration in the roller was 0.25 lb/gal; this is the same solution concentration as picloram at 2 lb/A sprayed at 8.5 gpa. The solution concentration was increased for the pipe-wick applicator to picloram at 0.5 lb/gal since the pipe-wick applied about half the total volume per acre as the roller applicator. The roller and pipe-wick applicator height was adjusted to treat the top one-half of the tallest leafy spurge stems. The additive in the roller and pipe-wick treatments was a 5% (v:v) oil concentrate (83% paraffin based petroleum oil plus 15% emulsifier). The plots were 15 by 150 ft and treatments were replicated twice at each site in a randomized complete block design. In June 1981 each plot was divided into six 7.5 by 50 ft subplots for retreatments of 2,4-D, picloram 2S, dicamba or no treatment except the fall Valley City site which was retreated in August 1981.

Original 1980 whole plot treatments were reapplied in 1982 with several of the treatments changed. A carpet applicator was substituted for the roller applicator. The granular picloram treatments were replaced by picloram applied with the pipe-wick or carpet applicator with two passes, the second pass in the opposite direction to the first. Dicamba at 8.0 lb/A spray applied replaced the picloram plus oil concentrate pipe-wick applied treatment. The carpet applicator was designed by Magnolia Spray Equipment Corp., Jackson, MS, and consists of a 1 by 8 ft carpet attached to a rectangular spray box. The herbicide solution was sprayed onto the backside of the carpet through nozzles inside the spray box. Excess solution was returned to the spray tank. The picloram solution on the carpet applicator was 0.25 lb/gal and 0.4 lb/gal for two and one-pass applications, respectively. The whole plots were retreated in 1982 with the original treatment except picloram at 2 lb/A was reapplied to the control subplot only since subplots receiving annual retreatments maintained satisfactory leafy spurge control. The experimental site at the Sheyenne National Grasslands was treated in the fall of 1982 to establish an equal number of spring and fall treatment sites. Subplot retreatments were applied again in 1983,

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1984, and 1985. Evaluations are based on visual percent stand reduction as compared to the control.

In general, leafy spurge control was higher from spring-applied treatments compared to similar fall applied treatments (Table). Previous research at North Dakota State University has shown spring or fall applied treatments to give similar leafy spurge control; however, in this study the fall treatments were applied to leafy spurge plants that had been mowed in July of each year through 1984. Thus, the plants were shorter and in the vegetative growth stage compared to the normal fall growth stage. This reduced the plant area treated and may have resulted in less herbicide uptake and translocation. The plants were not mowed in 1985 so this variable should not affect control from fall treatments in the future.

Picloram (2S) at 1 and 2 lb/A provided the best long-term leafy spurge control regardless of retreatment (Table). Picloram at 1 and 2 lb/A provided 77 and 91% control as spring applied treatments, but only 51 and 63% control as fall applied treatments, respectively. Leafy spurge control was similar regardless of retreatments. Thus, when higher rates of picloram are applied every few years, there is little advantage in using more than 1 lb/A or in applying annual retreatment.

Dicamba at 8 lb/A alone spring applied averaged 42% control, but control increased to 96 and 92% with retreatments of picloram at 0.25 lb/A or picloram + 2,4-D at 0.25 + 1 lb/A (Table). Leafy spurge control from fall applied dicamba at 8 lb/A averaged 16% and increased to an average of 57% following retreatments of picloram at 0.25 lb/A, picloram + 2,4-D at 0.25 + 1 lb/A or dicamba at 2 lb/A.

Annual application of 2,4-D, the most economical treatment in the study provided only 2 and 21% leafy spurge control as a fall and spring applied treatment, respectively (Table). Leafy spurge control was increased to 72% when the 2,4-D original treatment was retreated with picloram + 2,4-D at 0.25 + 1 lb/A annually in the spring, but the same fall applied treatment provided only 22% control.

The annual retreatments that provided the highest leafy spurge control were picloram + 2,4-D at 0.25 + 1 lb/A, picloram at 0.25 lb/A and dicamba at 2 lb/A (Table). These retreatments averaged 74 and 52% leafy spurge control as spring and fall applied treatments, respectively, when averaged over all whole plot treatments. Annual retreatments of 2,4-D or dicamba at 1 lb/A averaged only 53 and 29% leafy spurge control as spring and fall applied treatments averaged over whole plot treatments, respectively. Leafy spurge control was increased 9% when 2,4-D was added to picloram as an annual treatment spring applied, but not when fall applied. Thus, the most practical retreatment when considering both cost and control were picloram at 0.25 lb/A alone or picloram + 2,4-D at 0.25 + 1 lb/A, but dicamba at 2 lb/A would be the retreatment of choice where picloram could not be applied such as in areas with water tables 10 ft or less below the surface.

No treatment using a reduced-volume applicator maintained satisfactory control alone. The reduced volume applicators would not have an economic advantage if several annual retreatments were required for satisfactory leafy spurge control. Several herbicide treatment alternatives provided 80% or more leafy spurge control 5 years after the initial treatment, but no treatment program had eradicated leafy spurge.

Table. Leafy spurge control in North Dakota following a five-year management program.

Whole Plot: Treatment[a] 1980	Rate	Soln conc[b]	Treatment[a] 1982	Rate	Soln conc[b]	Retreatment subplot 1981, 1983-1985/rate lb/A: 2,4-D 1.0	Dicamba 1.0	Dicamba 2.0	Picloram 0.25	Picloram + 2,4-D 0.25 + 1.0	Control 0	Mean
	(lb/A)	(lb/gal)		(lb/A)	(lb/gal)	(% control)						
Spring applied												
2,4-D	2.0	0.24	2, 4-D	2.0	0.24	21	21	41	58	72	9	36
Picloram 2%G	1.0	....	Picloram (carpet-2 pass)	...	0.25	40	47	65	59	78	42	55
Picloram 2%G	2.0	....	Picloram (wick-2 pass)	...	0.5	86	85	91	94	94	82	89
Picloram 2S	1.0	0.13	Picloram 2S	1.0	0.13	81	72	92	78	91	46	77
Picloram 2S	2.0	0.25	Picloram 2S[c]	2.0	0.25	86	96	96	92	88	86	91
Picloram (Roller)	....	0.25	Picloram (carpet)	...	0.25	18	26	44	51	54	22	36
Picloram + oil conc. (Roller)	....	0.25	Picloram (carpet)	....	0.25	38	40	79	63	83	31	55
Picloram (Wick)	....	0.5	Picloram (wick)	...	0.5	55	50	46	78	74	8	52
Picloram + oil conc. (Wick)	....	0.5	Dicamba	8.0	1.0	71	72	80	96	92	42	75
Control	....	....	Control	...	....	12	17	73	61	70	0	39
Mean						52	53	70	73	80	38	

LSD (0.05) whole plot = 8; subplot = 6; whole plot x sub-plot = 18

(Table 1 continued on the following page.)

Whole Plot Treatment[a] 1980	Rate	Soln conc[b]	Treatment[a] 1982	Rate	Soln conc[b]	Retreatment subplot 1981, 1983-1985/rate lb/A: 2,4-D 1.0	Dicamba 1.0	Dicamba 2.0	Picloram 0.25	Picloram + 2,4-D 0.25 + 1.0	Control 0	Mean
	(lb/A)	(lb/gal)		(lb/A)	(lb/gal)	(% control)						
Fall applied												
2, 4-D	2.0	0.24	2, 4-D	2.0	0.24	2	20	31	25	22	0	17
Picloram 2%G	1.0	....	Picloram (carpet-2 pass)	...	0.25	19	48	68	46	56	21	43
Picloram 2%G	2.0	....	Picloram (wick-2 pass	...	0.5	41	32	57	51	49	26	43
Picloram 2S	1.0	0.13	Picloram 2S	1.0	0.13	33	44	45	46	66	73	51
Picloram 2S	2.0	0.25	Picloram 2S[c]	2.0	0.25	44	52	76	63	70	75	63
Picloram (Roller)	....	0.25	Picloram (carpet)	...	0.25	30	23	69	43	52	31	41
Picloram + oil conc. (Roller)	....	0.25	Picloram (carpet)	...	0.25	46	40	73	50	72	39	53
Picloram (Wick)	....	0.5	Picloram (wick)	...	0.5	21	25	55	25	48	15	32
Picloram + oil conc. (Wick)	....	0.5	Dicamba	8.0	1.0	17	27	61	61	50	16	39
Control	....	....	Control	...	....	0	15	41	51	47	0	27
Mean						25	33	58	46	53	31	
LSD (0.05) whole plot = 15; subplots = 12; whole plot x subplot = 36												

[a]Spray applied except the treatments identified as roller, wick or carpet applicator applied.

[b]Herbicide: water (v/v)

[c]Applied to control subplot only.

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Low rate annual picloram and 2,4-D combination treatments for leafy spurge control[1]

RODNEY G. LYM and CALVIN G. MESSERSMITH

Previous research at North Dakota State University has shown that annual treatments of picloram + 2,4-D for 3 to 5 years will give similar leafy spurge control to expensive high rate picloram treatments. Picloram + 2,4-D at 0.25 + 1.0 lb/A generally gives 20 to 30% better leafy spurge control than picloram at 0.25 lb/A alone, but the benefit of a herbicide combination declines as the picloram or 2,4-D rate increases. Picloram + 2,4-D at 0.5 + 1.0 lb/A tends to give only 5 to 10% better control than picloram at 0.5 lb/A alone. The purpose of this experiment was to evaluate long-term leafy spurge control from annual treatments of picloram + 2,4-D at relatively low application rates.

The experiment was established at four locations in North Dakota. Spring treatments were applied on June 13, 18 and 19, 1984 at Dickinson, Hunter and Valley City, respectively, and the fall treatments were applied on September 5 and 18, 1984 at Valley City and the Sheyenne National Grasslands near McLeod, respectively. The soil was a loamy fine sand at Dickinson, a silty clay loam at Hunter, Sheldon and the Sheyenne National Grasslands and a loam at Valley City. Dickinson, located in western North Dakota, generally receives much less precipitation than the other two sites located in eastern North Dakota. The spring and fall treatments were applied annually in June or September 1984 and 1985. The herbicides were applied with a tractor-mounted sprayer delivering 8.5 gpa at 35 psi. All plots were 10 by 30 ft in a randomized complete block design with four replications at each site except Hunter, which had 8 by 25 ft plots, and 3 replications. Evaluations were based on a visible estimate of percent stand reduction as compared to the control.

Picloram at 0.125, 0.25, 0.375 and 0.5 lb/A provided 12, 13, 41 and 46% leafy spurge control, respectively, as a spring applied treatment but only 2, 7, 4 and 15% control, respectively, as a fall applied treatment 12 months following initial application (Table). The addition of 2,4-D to picloram tended to increase leafy spurge control slightly from spring but not fall applied treatments. The slight increase in control was similar regardless of 2,4-D rate. Control was similar to previous experiments after one application for spring applied treatments, but lower than expected for fall treatments. The weather was very dry

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in North Dakota during the fall of 1984 and leafy spurge was under moisture stress when the treatments were applied. These conditions probably account for the lower than expected control in 1985. This experiment must be continued for several years to determine if the presently used picloram at 0.25 to 0.5 lb/A + 2,4-D at 1.0 lb/A treatment is the most cost effective application rate for an annual leafy spurge control program.

Table. Leafy spurge control from annual picloram or picloram plus 2,4-D treatments spring or fall applied at four locations in North Dakota. (Lym and Messersmith).

		Application time/location/evaluation date											
		Spring							Fall				
		Hunter		Dickinson		Valley City			Sheyenne		Valley City		
Treatment	Rate	June	Aug	June	Sept	June	Aug	Mean[a]	June	Aug	June	Aug	Mean[a]
	(lb/A)	(%)											
Picloram	0.125	38	3	0	0	5	4	12	59	3	0	0	2
Picloram	0.25	11	35	3	24	24	21	13	66	12	20	1	7
Picloram	0.375	78	83	10	46	44	34	41	72	5	47	3	4
Picloram	0.5	81	93	15	61	51	48	46	98	18	85	13	15
Picloram+2,4-D	0.125+0.125	3	28	8	14	13	38	8	52	5	21	0	2
Picloram+2,4-D	0.125+0.25	0	13	8	53	8	20	6	38	1	10	0	0
Picloram+2,4-D	0.125+0.5	7	3	10	72	3	64	7	35	4	4	0	2
Picloram+2,4-D	0.25+0.125	31	73	4	64	21	87	18	55	8	11	0	2
Picloram+2,4-D	0.25+0.25	48	76	15	77	19	92	26	58	4	20	0	2
Picloram+2,4-D	0.25+0.5	41	50	11	85	24	92	24	50	1	18	0	1
Picloram+2,4-D	0.375+0.125	74	76	6	67	38	73	36	91	8	48	8	8
Picloram+2,4-D	0.375+0.25	88	82	5	96	45	80	42	65	4	44	2	3
Picloram+2,4-D	0.375+0.5	33	46	15	98	47	81	31	80	26	50	3	14
Picloram+2,4-D	0.5+0.125	88	88	9	98	73	69	54	81	15	54	3	9
Picloram+2,4-D	0.5+0.25	88	73	9	96	65	80	51	94	9	55	5	7
Picloram+2,4-D	0.5+0.5	85	70	10	98	75	75	54	97	36	42	8	22
Picloram+2,4-D	0.25+1.0	17	18	18	86	48	94	29	68	3	27	4	3
LSD (0.05)		31	36	11	26	33	27	18	31	11	30	8	8

[a]Average control 12 months following the original 1984 treatment date.

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Spring or fall applied granular picloram and dicamba for leafy spurge control[1]

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Granular and liquid formulations of picloram and dicamba were compared for leafy spurge control in two experiments established in 1980 on June 25 and September 3 near Valley City. Eight experiments to compare picloram 2% and 10%G formulations were established on September 14, 1982 and June 10, 1983 near Sheldon, ND, September 9, 1982, June 21, 1983, June 13 and September 11, 1984 near Dickinson, and June 14 and September 18, in the Sheyenne National Grasslands. Blank pellets were included in the experiments conducted at Sheldon so the number of pellets applied per plot was similar to improve uniformity of distribution of the picloram 10%G formulation. All experiments were in a randomized complete block design with four replications and 10 by 30 ft plots. The granules were applied uniformly by hand, while the liquid formulations were applied with a tractor-mounted sprayer at 8.5 gpa and 35 psi. Evaluations were based on percent stand reduction compared to the untreated control. A significant interaction between site and treatments occurred, so experimental sites will be discussed individually.

Leafy spurge control with picloram and dicamba was better from fall than spring applied treatments at Valley City, especially when evaluated 24 to 60 months after treatment (Table 1). The control averaged across all treatments after 24, 48 and 60 months was 54, 22 and 13% for spring applications and 78, 62 and 26% for fall applications, respectively. Fall applied dicamba at 8.0 lb/A and picloram at 2 lb/A as liquids provided similar control after 5 years, but control with granular picloram was better than with granular dicamba. Dicamba and picloram applied in the spring of 1980, generally did not give satisfactory leafy spurge control by 1982 and 1983, respectively. The exception was picloram at 2.0 lb/A, which provided satisfactory control until 1984. Only fall applied picloram 2%G at 1.5 and 2.0 lb/A provided satisfactory leafy spurge control after 48 months at 83 and 86%, respectively, but no treatment provided satisfactory control 60 months after application.

Picloram 2%G and 10%G at equal rates generally provided similar leafy spurge control at both Sheldon and Dickinson I (Table 2). Fall applications of picloram 2%G and 10%G at all application rates, except 2.0 lb/A, provided better leafy spurge control after 9 months than spring applications after 3 months. This difference could be due to insufficient moisture to completely disperse the granules following the June application, because the treatments generally were similar 12 and 24 months after application. Leafy spurge control in 1985 at Sheldon was similar to control in 1984. However, the treat-

[1] Cooperative investigation by Dep. of Agron. and ARS, U.S. Dep. of Agric. Published with the approval of the Agric. Exp. Sta., North Dakota State Univ., Fargo.

ments at Dickinson did not provide satisfactory leafy spurge control in 1985, so specific evaluations were not taken. The soil at Sheldon is very sandy compared to the mostly clay soil at Dickinson which may have allowed deeper picloram movement in the soil profile and thus better long-term leafy spurge root control at Sheldon than Dickinson.

Leafy spurge control with picloram at 1.0 and 2.0 lb/A was similar for the 2%G and 10%G when blanks were added, but was much worse with 10%G than 2%G pellets without blanks (Table 2). Since 80% fewer pellets per acre are applied with picloram 10%G than with 2%G, uniform distribution with hand-held application equipment was difficult which probably accounted for the decreased control.

Visible grass injury was negligible with either picloram formulation. In general, leafy spurge control with picloram at 2.0 lb/A declined more rapidly when the liquid (2S) formulation was used compared to 2%G or 10%G.

Similar experiments were begun in 1984 using a new formulation of picloram 10%G with smaller pellets, which resulted in more pellets per square foot than the previous 10%G formulation at similar rates. Picloram 10%G gave similar leafy spurge control to the 2%G formulation at all application rates except 0.5 lb/A (Table 2). Blanks were not mixed with the new 10%G formulation, but a uniform distribution still was obtained. Control was much lower at Dickinson II than at Sheyenne, which again probably was due to deeper picloram movement in the sandy soil at Sheyenne than the clay soil at Dickinson. Unlike previous experiments, spring application of picloram granules provided better leafy spurge control than fall applications when evaluated 12 months after treatment. Fall precipitation was below normal and the soil was very dry until late October in 1984. The dry soil conditions after application apparently caused poor long-term control despite adequate moisture in 1985.

Granular and liquid formulations of dicamba and picloram generally provided similar control at comparable rates. Picloram 2%G and 10%G provided similar leafy spurge control when blanks were included with the 10%G pellets or the number of 10G pellets per square foot was increased by use of a smaller pellet. Generally spring and fall treatment provided similar long-term control except when application was made during very dry conditions. Picloram granules provided better long-term control in sandy compared to clay soils.

Table 1. Spring and fall applied granular picloram and dicamba for leafy spurge control at Valley City, ND. (Lym and Messersmith).

		Application and evaluation date																		
		Spring treatment (25 June 1980)									Fall treatment (3 Sept 1980)									
Herbicide	Rate	6-81	9-81	6-82	9-82	6-83	9-83	6-84	9-84	6-85	6-81	9-81	6-82	9-82	6-83	9-83	6-84	9-84	6-85	8-85
	(lb/A)	(% control)																		
Picloram 2%G	1.0	97	80	53	25	44	22	10	8	3	95	86	84	55	76	52	51	52	18	10
Picloram 2%G	1.5	98	89	87	22	77	38	29	26	11	99	100	100	96	98	97	87	83	59	48
Picloram 2%G	2.0	99	98	90	53	85	72	56	62	28	100	100	99	100	100	98	93	86	68	63
Dicamba 5%G	4.0	74	55	9	3	4	0	4	0	0	94	74	43	31	31	29	18	20	17	9
Dicamba 5%G	6.0	82	54	25	3	16	5	4	3	1	96	99	89	58	55	55	41	40	22	6
Dicamba 5%G	8.0	91	75	45	19	29	6	5	6	0	99	100	98	83	84	78	66	67	39	20
Picloram 2S	2.0	100	99	98	90	94	79	64	71	54	100	100	100	100	98	94	79	78	50	28
Dicamba 4S	8.0	94	74	28	12	42	13	7	5	4	99	99	100	97	92	83	69	72	47	33
LSD (0.05)		9	14	21	17	20	11	11	12	20	3	10	22	29	24	24	29	23	26	23

Table 2. Leafy spurge control using picloram 2%G, 10%G and 2S as spring or fall applied treatment. (Lym and Messersmith).

Picloram formulation	Rate	Evaluation date 1983 June	1983 Aug	1984 June	1984 Aug	1985 June	1985 Aug	1983 June	1983 Aug	1984 June	1984 Aug	1985 June	1985 Sept
	(lb/A)	(% control)											
Applied Fall 1982		Sheldon						Dickinson I					
2%G + blanks	0.5	66	26	8	21	11	16	38	5	18	5	…	…
2%G + blanks	1.0	86	41	29	33	31	18	69	15	42	13	…	…
2%G + blanks	1.5	87	67	48	48	47	24	90	37	71	51	…	…
2%G	2.0	99	76	80	66	71	44	96	53	79	64	…	…
10%G + blanks	0.5	39	11	3	31	0	0	34	9	19	0	…	…
10%G + blanks	1.0	83	60	52	56	39	30	84	21	45	36	…	…
10%G + blanks	1.5	81	60	43	58	54	38	88	35	55	47	…	…
10%G + blanks	2.0	87	63	77	56	65	45	89	40	75	64	…	…
10%G	1.0	53	26	11	13	18	13	…	…	…	…	…	…
10%G	2.0	89	61	45	45	52	57	…	…	…	…	…	…
Liquid (2S)	2.0	94	67	55	44	30	35	94	42	60	41	…	…
LSD (0.05)		16	30	19	23	24	25	18	28	30	33	…	…
Applied Spring 1983													
2%G + blanks	0.5	…	28	27	10	21	8	…	38	28	12	…	…
2%G + blanks	1.0	…	38	58	13	55	14	…	57	53	43	…	…
2%G + blanks	1.5	…	86	95	36	92	50	…	62	83	60	…	…
2%G	2.0	…	97	94	69	93	62	…	76	89	65	…	…
10%G + blanks	0.5	…	26	11	6	18	4	…	25	20	2	…	…
10%G + blanks	1.0	…	54	61	16	52	28	…	32	42	23	…	…
10%G + blanks	1.5	…	74	70	26	58	35	…	78	75	56	…	…
10%G + blanks	2.0	…	92	92	56	92	56	…	63	76	70	…	…
Liquid (2S)	2.0	…	93	79	39	76	57	…	96	94	51	…	…
LSD (0.05)			22	14	14	23	15	…	23	19	29	…	…
Applied Spring 1984		Sheyenne						Dickinson II					
2%G	0.5	…	…	…	83	89	53	…	…	…	0	0	0
2%G	1.0	…	…	…	96	99	83	…	…	…	38	48	8
2%G	1.5	…	…	…	96	100	97	…	…	…	43	62	13
2%G	2.0	…	…	…	98	100	98	…	…	…	83	88	53
10%G	0.5	…	…	…	64	75	19	…	…	…	3	0	4
10%G	1.0	…	…	…	95	99	84	…	…	…	31	43	23
10%G	1.5	…	…	…	97	99	94	…	…	…	56	45	16
10%G	2.0	…	…	…	97	99	94	…	…	…	72	56	31
Liquid (2S)	2.0	…	…	…	98	100	99	…	…	…	98	80	28
LSD (0.05)		…	…	…	8	10	16	…	…	…	23	24	21

Picloram formulation	Rate	Evaluation date 1983 June	1983 Aug	1984 June	1984 Aug	1985 June	1985 Aug	1983 June	1983 Aug	1984 June	1984 Aug	1985 June	1985 Sept
	(lb/A)	(% control)											
Applied Fall 1984													
2%G	0.5	…	…	…	…	94	57	…	…	…	…	71	16
2%G	1.0	…	…	…	…	100	91	…	…	…	…	85	39
2%G	1.5	…	…	…	…	100	96	…	…	…	…	97	56
2%G	2.0	…	…	…	…	100	97	…	…	…	…	98	81
10%G	0.5	…	…	…	…	82	42	…	…	…	…	46	15
10%G	1.0	…	…	…	…	96	81	…	…	…	…	79	36
10%G	1.5	…	…	…	…	99	91	…	…	…	…	91	45
10%G	2.0	…	…	…	…	99	91	…	…	…	…	95	68
Liquid (2S)	2.0	…	…	…	…	100	99	…	…	…	…	99	47
LSD (0.05)		…	…	…	…	6	16	…	…	…	…	9	17

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Leafy spurge control in a wooded area of the Sheyenne National Grasslands[1]

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Leafy spurge is a major problem in wooded areas, shelterbelts, and around homes. The purpose of this experiment was to evaluate the controlled droplet applicator (CDA) for application of picloram, dicamba, and glyphosate to leafy spurge growing under trees.

The experiment was established in a wooded area of the Sheyenne National Grasslands near McLeod, ND, on September 21, 1982. The leafy spurge was 28 to 34 inches tall with slight frost injury. The trees were *Populus* spp. (cottonwood and aspen) and ranged from 6 to 16 inches in diameter with some saplings intermixed. The weather was clear, 69º F, 42% relative humidity, and the soil was moist. The plots were 25 by 50 ft and replicated four times in a randomized complete block design. The treatments were applied with single coverage at walking speed, except some overlap occurred as the applicator tried to prevent skipped areas while walking around trees. Approximately 0.8 gal/A of herbicide solution was applied. Evaluations were based on visual estimates of percent stand reduction as compared to the control.

Herbicide	Herbicide concentration	Control 1983 June	Control 1983 August	Control 1984 June	Control 1984 August	Control 1985 June
	(lb/gal)	(%)				
Picloram	0.25	92	60	49	48	5
Picloram	0.5	97	69	56	35	0
Picloram	0.67	100	77	57	49	31
Picloram+2,4-D	0.2+0.4	92	48	28	42	5
Dicamba	1.33	92	75	60	30	1
Glyphosate	1.5	93	76	72	43	44
LSD (0.05)		9	35	38	16	26

All treatments provided 92% or better leafy spurge control when evaluated in June 1983 but control declined rapidly thereafter. The addition of 2,4-D to picloram did not improve leafy spurge control compared to picloram applied alone. Glyphosate at 1.5

[1] Cooperative investigation Dep. of Agron. and ARS, U.S. Dep. of Agric. Published with the approval of the Agric. Exp. Stn., North Dakota State Univ., Fargo.

lb/gal and picloram at 0.67 lb/gal provided the best long-term control, but retreatment would have been necessary for both treatments by 1984. Leafy spurge control was better from all treatments than would have been expected if similar treatments had been applied in an open field. Reinfestation from seedlings was minimal even in the glyphosate treated plots. Grass injury was still very evident in plots treated with glyphosate 24 months following application. No visible tree injury resulted from any treatment.

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Screening trials of various herbicides, herbicide combinations and surfactants for leafy spurge control[1]

RODNEY G. LYM and CALVIN G. MESSERSMITH[1]

Four experiments to evaluate several herbicides and additives for leafy spurge control were established near Sheldon, ND, and on the Sheyenne National Grasslands near McLeod, ND, in 1984 and 1985. The herbicides were applied using a tractor-mounted sprayer delivering 8.5 gpa at 35 psi. All plots were 10 by 30 ft in a randomized complete block design with four replications. Evaluations were based on percent stand reduction as compared to the control.

Previous research at North Dakota State University has shown that amitrole alone provides inadequate leafy spurge control, but does translocate in the plant as evidenced by inhibition of chlorophyll formation in new stem growth from the root. Picloram was applied with amitrole on June 10, 1983 in an effort to increase picloram translocation into the leafy spurge root system. Leafy spurge was flowering and 18 to 24 inches tall. Leafy spurge regrowth in plots treated with picloram + amitrole lacked chlorophyll 1 year after application, but plant density was similar to plots treated with picloram alone (Table 1). There was a tendency for leafy spurge control to be increased when amitrole was added to picloram compared to picloram alone 24 months following application, but grass injury from amitrole would prohibit use in pasture and rangeland.

Research using a roller applicator to apply picloram in pasture showed increased leafy spurge control with a boom-end marking foam additive in one experiment, but not when other surfactants or oils were added. An experiment was established on June 14 and 15, 1984 at the Sheyenne National Grasslands and Sheldon, respectively, to evaluate the foam as an additive to picloram spray applied. The leafy spurge was 10 to 18 inches tall and beginning seed set at both sites. Initial control was better at Sheyenne than Sheldon regardless of treatment, but the foam additive did not increase control compared to picloram alone at either site (Table 1). No treatment provided satisfactory leafy spurge control 15 months after application.

Previous research has shown picloram + 2,4-D at 0.25 + 1.0 lb/A provides better leafy spurge control compared to picloram alone. The third experiment was established to compare the alkanolamine and mixed amine salts (EH-736) of 2,4-D for leafy spurge control alone and when tank mixed with picloram. The experiment was begun on the same dates and locations as the additive experiment. Leafy spurge control was similar at

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Sheldon when the 2,4-D formulations were applied alone or with picloram (Table 1). However, at the Sheyenne National Grasslands there was a tendency for better leafy spurge control when picloram was combined with EH-736 than the alkanolamine formulation. The 2,4-D formulations provided similar control when applied alone. Research was begun in 1985 to further evaluate EH-736 as an additive to picloram for leafy spurge control.

AC 252,925 was applied for leafy spurge control at three different growth stages in 1984. Various rates of the compound were applied on May 29 when leafy spurge was in the vegetative growth stage, on June 15 during flowering and seed set, and on September 18 during vigorous fall regrowth following a summer dormancy period. AC 252,925 provided good initial top growth control especially at 2.0 lb/A but grass damage was severe at all application dates (Table 2). Control in May 1985 averaged across all dates and rates was 91% but grass injury was severe. Leafy spurge control decreased rapidly 12 to 15 months after application, but grass damage remained high.

Table 1. Leafy spurge control with picloram in combination with amitrole, a foam additive and 2, 4-D. (Lym and Messersmith).

		Location/evaluation date									
		Sheldon							Sheyenne		
		June 1984		Aug 1984		May 1985		Aug 1985	Aug 1984	May 1985	Aug 1985
Treatment	Rate	Control	Grass injury	Control	Grass injury	Control	Grass injury	Control	Control	Control	Control
	(lb/A)	(%)									
Experiment 1											
Amitrole + picloram	1.25+0.5	34	10	13	5	28	…	…	…	…	…
Amitrole + picloram	2.5+0.5	38	25	25	18	21	…	…	…	…	…
Amitrole + picloram	5.0+0.5	50	75	23	45	20	…	…	…	…	…
Amitrole + picloram	1.25+1.0	73	12	34	3	40	…	…	…	…	…
Amitrole + picloram	2.5+1.0	79	30	31	20	61	…	…	…	…	…
Amitrole + picloram	5.0+1.0	74	72	35	53	49	…	…	…	…	…
Picloram	0.5	40	0	18	0	3	…	…	…	…	…
Picloram	1.0	64	0	28	0	29	…	…	…	…	…
Amitrole	5.0	25	63	16	57	11	…	…	…	…	…
LSD (0.05)		27	16	25	22	31	…	…	…	…	…
Experiment 2											
Picloram	0.5	…	…	57	…	25	…	4	94	91	20
Picloram	1.0	…	…	87	…	81	…	21	98	99	13
Picloram + foam[a]	0.5+0.5%	…	…	51	…	26	…	4	95	96	2
Picloram + foam[a]	1.0+0.5%	…	…	81	…	70	…	8	98	99	44
LSD (0.05)		…	…	21	…	26	…	12	5	7	24

		Location/evaluation date									
		Sheldon							Sheyenne		
		June 1984		Aug 1984		May 1985		Aug 1985	Aug 1984	May 1985	Aug 1985
Treatment	Rate	Control	Grass injury	Control	Grass injury	Control	Grass injury	Control	Control	Control	Control
	(lb/A)	(%)									
Experiment 3											
Picloram	0.25	…	…	35	…	11	…	…	76	23	4
Picloram	0.5	…	…	37	…	9	…	…	95	75	43
Picloram + 2,4-D alkanolamine	0.25+1.0	…	…	21	…	4	…	…	78	14	6
EH-736[b]	4.0	…	…	19	…	4	…	…	47	7	13
Picloram +EH-736[b]	0.25+1.0	…	…	22	…	8	…	…	94	72	23
2,4-D alkanolamine	4.0	…	…	24	…	1	…	…	42	20	7
LSD (0.05)				21		9			15	25	15

[a]Boom-end marking foam (Stamfoam, Stam Manufacturing Co., Wateska, IL)

[b]Mixed amine salts of 2, 4-D (2:1 dimethylamine:diethalolamine

Table 2. Leafy spurge control with AC 252,925 applied at various times during the growing season. (Lym and Messersmith).

		Evaluation/date					
		Aug 1984		May 1985		Aug 1985	
Treatment	Rate[a]	Control	Grass injury	Control	Grass injury	Control	Grass injury
	(lb/A)	---------- (%) ----------					
Applied 29 May 84							
AC 252,925	0.5	23	7	95	60	18	20
AC 252,925	1.0	68	58	75	80	8	60
AC 252,925	2.0	92	45	99	90	3	80
Applied 15 June 84							
AC 252,925	0.5	76	22	65	50	0	20
AC 252,925	1.0	79	23	94	90	0	80
Ac 252,925	2.0	93	38	99	90	66	70
Applied 18 Sept 84							
Picloram	2.0	–	–	100	10	97	0
AC 252,925	0.5	–	–	97	100	6	20
AC 252,925	1.0	–	–	99	100	17	50
AC 252,925	2.0	–	–	100	100	35	80
LSD (0.05)		18	23	24	3	35	5

[a]All AC 252,925 treatments included 0.5% surfactant WK (v/v)

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Dikegulac in combination with 2,4-D and picloram for leafy-spurge control[1]

RODNEY G. LYM and C. G. MESSERSMITH

Previous studies have shown dikegulac (the sodium salt of dikegulac, trade name Atrinal by Maag Agrochemicals, Vero Beach, Florida) to be synergistic with 2,4-D and picloram for leafy spurge control. Dikegulac causes temporary inhibition of plant growth, reduction or elimination of flowering and promotion of axillary plant growth. Leafy spurge response to dikegulac decreases as the plant matures. The purpose of these experiments was to evaluate the synergism of dikegulac with picloram or 2,4-D in the field both as a tank mix and split application.

The experiments were established at Lisbon, ND in an unused quarry with a heavy infestation of leafy spurge. The first two experiments were established on 26 May 1982 when the leafy spurge was in the yellow bract growth stage and before true flower initiation. The plots were 10 by 30 ft, and treatments were replicated four times in a randomized complete block design. The treatments were applied in 8.5 gpa at 35 psi. Evaluations were based on visual percent stand reduction as compared to the control.

Dikegulac at 0.5, 1.0 and 2.0 lb/A was applied alone and tank-mixed with picloram at 1.0 or 2.0 lb/A and 2,4-D at 2.0 lb/A in the first experiment. Leafy spurge plants treated with dikegulac alone at one month after application were stunted and had many axillary branches, and most flowers had been aborted. In general, the number of axillary branches increased as the dikegulac rate increased. By the end of the growing season, plants treated with dikegulac at 2 lb/A still had many axillary branches but plants treated at the lower rates had resumed normal growth. Leafy spurge control was increased when picloram at 1.0 lb/A was applied with dikegulac (Table 1). Leafy spurge control was 19 and 26% at 15 and 29 months following application of picloram at 1.0 lb/A, respectively, but was 73 and 61%, respectively, when averaged across the tank mixtures of dikegulac at 0.5, 1.0, or 2.0 lb/A. Dikegulac tank-mixed with picloram at 2.0 lb/A or 2,4-D did not increase leafy spurge control compared to the herbicides applied alone.

Dikegulac was applied as a tank mix or split treatment with picloram and 2,4-D in the second experiment. Dikegulac alone at 0.5 and 1.0 lb/A was applied on 26 May 1983. Picloram or 2,4-D at 1.0 lb/A were applied on 30 June 1983, as a split treatment alone or as a tank mix treatment with dikegulac. The leafy spurge was in the true flower growth stage and beginning seed set. Dikegulac had no observable effect on leafy spurge when applied on 26 May 1983. However, leafy spurge control with picloram at 1.0 lb/A increased slightly when dikegulac was used as a pretreatment or a tank mix compared to

[1] Cooperative investigation Dep. of Agron. and ARS, U.S. Dep. of Agric. Published with the approval of the Agric. Exp. Stn., North Dakota State Univ., Fargo.

picloram applied alone (Table 2). Leafy spurge control with 2,4-D was not affected by dikegulac.

The third experiment was similar to the second experiment with dikegulac alone applied on 7 September 1982 and 2,4-D or picloram applied on 4 October 1982 either alone for the split treatments or tank mixed with dikegulac. Leafy spurge was under moisture stress on 7 September, and the plants were red and yellow with slight frost damage by 4 October. Dikegulac alone did not affect leafy spurge growth or control with picloram and 2,4-D when applied as a fall treatment to mature plants (Table 3).

Dikegulac had plant growth regulator activity on leafy spurge only early in the growing season. Thus, an experiment was begun in 1984 in a pasture near Hunter, ND, to evaluate various combination treatments of picloram and dikegulac applied early in the growing season for leafy spurge control. Treatments were applied either on 10 May when leafy spurge was 4 to 6 inches tall and in the vegetative growth stage, or on 22 May when the plants were 12 to 14 inches tall with yellow bracts but not yet flowering. The experimental design and application methods were similar to those previously described.

Leafy spurge control following early spring application of picloram plus dikegulac was inconsistent (Table 4). Leafy spurge plants treated with dikegulac alone in 1984 were less stunted and had fewer axillary branches compared to similar treatments in 1982. Leafy spurge control tended to increase when dikegulac was applied with picloram at 0.5 lb/A compared to picloram alone. However, control was similar or tended to decline when dikegulac was applied with picloram at 0.75 or 1.0 lb/A.

Although there is a tendency for leafy spurge control to be improved from low rates of picloram plus dikegulac compared to picloram alone, this increase is not as great as when 2,4-D is added to picloram. Also, 2,4-D is more economical than dikegulac as a combination treatment with picloram for leafy spurge control.

Table 1. Leafy spurge control by 2,4-D or picloram applied alone or with dikegulac on 26 May 1982 near Lisbon, ND.

		Control			
		1983		1984	
Treatment	Rate	1 June	22 August	5 June	5 October
	(lb/A)	----------------------------------	(%)	----------------------------------	
Dikegulac + picloram	0.5+1.0	92	70	64	60
Dikegulac + picloram	0.5+2.0	100	90	68	63
Dikegulac + picloram	1.0+1.0	91	60	76	61
Dikegulac + picloram	1.0+2.0	100	83	87	85
Dikegulac + picloram	2.0+1.0	96	68	78	73
Dikegulac + picloram	2.0+2.0	99	94	90	89
Dikegulac + 2,4-D	0.5+2.0	15	3	3	3
Dikegulac + 2,4-D	1.0+2.0	15	3	0	0
Dikegulac+ 2,4-D	2.0+2.0	2	0	0	0
Dikegulac	0.5	1	0	0	0
Dikegulac	1.0	0	0	0	0
Dikegulac	2.0	2	0	0	0
Picloram	1.0	90	19	27	26
Picloram	2.0	96	98	72	75
2,4-D	2.0	12	0	0	0
LSD (0.05)		13	15	21	23

Table 2. Leafy spurge control by 2,4-D or picloram applied with dikegulac as a pretreatment or tank mix near Lisbon, ND.

		1982	Control	
		Application	1983	1982
Treatment	Rate	date	1 June	22 August
	(lb/A)		--------------- (%)	----------------
Dikegulac	0.5	30 June	0	0
Dikegulac	1.0	30 June	7	0
Picloram	1.0	30 June	90	9
2,4-D	1.0	30 June	14	0
Dikegulac + picloram (split)	0.5+1.0	26 May/30 June	94	19
Dikegulac + picloram (split)	1.0+1.0	26 May/30 June	92	16
Dikegulac + picloram (tank mix)	0.5+1.0	30 June	95	18
Dikegulac + picloram (tank mix)	1.0+1.0	30 June	82	9
Dikegulac + 2,4-D (split)	0.5+1.0	26 May/30 June	4	0
Dikegulac + 2,4-D (split)	1.0+1.0	26 May/30 June	4	0
Dikegulac + 2,4-D (tank mix)	0.5+1.0	30 June	1	0
Dikegulac + 2,4-D (tank mix)	1.0+1.0	30 June	9	0
LSD (0.05)			14	10

Table 3. Leafy spurge control by 2,4-D or picloram applied with dikegulac as a pretreatment or tank mix near Lisbon, ND.

Treatment	Rate	1982 Application date	Control 1 June 1983	Control 22 August 1983
	(lb/A)		(%)	
Dikegulac + picloram (tank mix)	0.5+1.0	7 Sept	72	1
Dikegulac + picloram (tank mix)	1.0+1.0	7 Sept	52	4
Dikegulac + picloram (split)	0.5+1.0	7 Sept/4 Oct	47	0
Dikegulac + picloram (split)	1.0+1.0	7 Sept/4 Oct	64	8
Dikegulac + 2,4-D (tank mix)	0.5+2.0	7 Sept	2	0
Dikegulac + 2,4-D (tank mix)	1.0+2.0	7 Sept	2	0
2,4-D	2.0	7 Sept	4	0
Picloram	1.0	7 Sept	57	8
LSD (0.05)			20	3

Table 4. Leafy spurge control by picloram and dikegulac tank mix treatments applied near Hunter, ND.

		Application date/control 84			
		10 May 84		22 May 84	
Treatment	Rate	Aug 1984	May 1985	Aug 1984	May 1985
	(lb/A)	(%)			
Dikegulac	0.25	0	0	1	0
Dikegulac	0.5	1	0	1	0
Dikegulac	1.0	1	2	0	0
Picloram	0.5	16	4	38	14
Picloram	0.75	53	7	31	49
Picloram	1.0	69	68	56	75
Dikegulac + picloram	0.25+0.5	32	16	38	28
Dikegulac + picloram	0.25+0.75	37	1	70	36
Dikegulac + picloram	0.25+1.0	43	0	81	36
Dikegulac + picloram	0.5+0.5	55	18	37	18
Dikegulac + picloram	0.5+0.75	51	31	55	44
Dikegulac + picloram	0.5+1.0	80	67	60	69
Dikegulac + picloram	1.0+0.5	24	5	24	1
Dikegulac + picloram	1.0+0.75	24	6	30	35
Dikegulac + picloram	1.0+1.0	50	36	48	43
LSD (0.05)		34	28	35	35

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Mowing as a pretreatment for leafy spurge control with herbicides[1]

RODNEY G. LYM and C. G. MESSERSMITH

Previous research has shown that annual mowing of leafy spurge tends to increase forage production and delay leafy spurge maturity. Leafy spurge mowed in mid-summer begins vigorous regrowth and may start to flower and set seed in the fall, whereas unmowed plants generally have leafless mature stems with 4 to 6 inch branches of new growth near the tip. Two experiments were established to evaluate mowing as a pretreatment to fall herbicide application for leafy spurge control in a pasture near Sheldon, ND. Leafy spurge was mowed on 2 August 1983 and picloram at 1.0 lb/A or 2,4-D at 2.0 lb/A were applied on 11 August, 18 August or 6 September 1983 in the first experiment. The leafy spurge was dormant prior to mowing but regrowth ranged from 2 to 3 inches tall on 11 August to flowering and 20 to 26 inches tall on 6 September. Leafy spurge was mowed on 2 August, 18 August or 6 September 1983 with all herbicide treatments applied on 22 September 1983 in the second experiment. Leafy spurge ranged from 24 inches tall, flowering and beginning seed set in plots mowed on 2 August to only 2 inches tall with few stems in plots mowed on 6 September. The plots were mowed with a rotary mower and herbicides were applied with a tractor-mounted sprayer delivering 8.5 gpa at 35 psi. All plots were 10 by 30 ft in a randomized complete block design with four replications. Air temperature was 84, 82, 71 and 46 F when herbicides were applied on 11 August, 18 August, 6 September and 22 September, respectively. Evaluations are based on visual estimate of percent stand reduction as compared to the control.

Leafy spurge control with picloram applied 16 and 35 days after mowing was similar to control of unmowed plants in Experiment I (Table). However, control 9 months after application was only 42% when picloram was applied 9 days after mowing, probably due to the limited leafy spurge regrowth for folíar absorption of picloram. Leafy spurge control with 2,4-D was 31 and 29% when applied to unmowed plants or 35 days after mowing, respectively. Control was only 3 and 6% when 2,4-D was applied 9 and 16 days after mowing, respectively. Mowing did not affect leafy spurge control one year after treatment.

Leafy spurge control with picloram in the second experiment was similar regardless of mowing date or no mowing at 9 months following application. However, 15 months after treatment control was 60 and 55% when picloram at 1-0 lb/A was applied 51 days after mowing or on unmowed plants, respectively, but only 13 and 25% when application was made 35 and 16 days after mowing, respectively. Leafy spurge control with 2,4-D

[1] Cooperative investigation Dep. of Agron. and ARS, U.S. Dep. of Agric. Published with the approval of the Agric. Exp. Stn., North Dakota State Univ., Fargo.

increased to 33 and 14% when applied 51 days after mowing compared to 10 and 6% with no mowing when evaluated 9 and 12 months after application, respectively. No other mowing date affected leafy spurge control with 2,4-D. Mowing alone tended to decrease leafy spurge density slightly with all mowing dates during the first year of the experiment. In general, leafy spurge control was not improved by a mowing pretreatment regardless of the mowing or herbicide application date and tended to decline if herbicides were applied earlier than 35 days after mowing.

Table. Leafy spurge control with picloram and 2,4-D applied on several dates in 1983 following mowing as a pretreatment.

Treatment	Rate	Days after mowing	Control 1984 June	Control 1984 August	Control 1985 June
	(lb/A)		-------------------	(%)	----------------
Experiment 1 (mowed 2 Aug 83)					
Mow + picloram (11 Aug)	1.0	9	42	6	8
Mow + 2,4-D (11 Aug)	2.0	9	3	5	2
Mow + picloram (18 Aug)	1.0	16	94	27	28
Mow + 2,4-D (18 Aug)	2.0	16	6	8	1
Mow + picloram (6 Sept)	1.0	35	88	25	20
Mow + 2,4-D (6 Sept)	2.0	35	29	6	2
Picloram (6 Sept)	1.0	…	97	30	13
2,4-D (6 Sept)	2.0	…	31	3	0
Mow only	...	…	7	0	0
LSD (0.05)			23	12	11
Experiment 2 (treated 22 Sept 83)					
Mow (2 Aug) + picloram	1.0	51	96	22	60
Mow (2 Aug) + 2,4-D	2.0	51	33	14	10
Mow (18 Aug) + picloram	1.0	35	91	30	13
Mow (18 Aug) + 2,4-D	2.0	35	18	2	0
Mow (6 Sept) + picloram	1.0	16	94	17	25
Mow (6 Sept) + 2,4-D	2.0	16	1	0	0
Mow (2 Aug 83)	…	…	5	2	3
Mow (18 Aug 83)	...	...	5	5	0
Mow (6 Sept 83)	...	...	3	4	3
Picloram	1.0	…	99	21	55
2,4-D	2.0	...	10	6	0
LSD (0.05)			16	8	18

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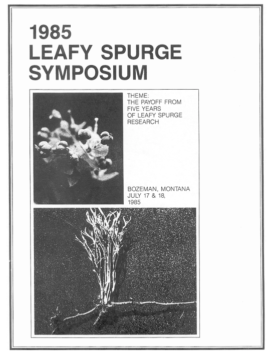

1985 Leafy Spurge Symposium Proceedings

Presentations

I. Scientific and research presentations

A. David G. Davis, USDA-ARS, MRRL, Fargo, ND. "The Status of Accession Numbering System and Procedures for Successful Regeneration of Leafy Spurge."

B. James H. Westwood and David D. Biesboer, Dept. of Botany, University of Minnesota, St. Paul, MN. "The Influence of Glyphosate on Endogenous Levels of Free IAA and Phenolic Compounds in Leafy Spurge."

C. Scott Nissen and Michael E. Foley, Dept. of Plant and Soil Science, Montana State University, Bozeman, MT. "The Physiology of Leafy Spurge Root Bud Dormancy."

D. Steve Harvey, Dept. of Entomology, Montana State University, Bozeman, MT. "Leafy Spurge Growth Response Following Cold Treatment to Break Fall Dormancy and Latex and Leaf Shape Variability in Leafy Spurge." (No report submitted)

E. Paul Mahlberg, Dept. of Biology, Indiana University, Bloomington, IN. "Starch Composition of *Euphorbia* latex."

F. J. R. Schaeffer and Shirley Gerhardt, Dept. of Plant and Soil Science, Montana State University, Bozeman, MT. "Cytogenetics of Leafy Spurge."

G. Norman E. Rees, USDA-ARS, Bozeman, MT. "Release of *Oberea erythrocephala* in Montana."

H. Bob Carlson, Dept. of Entomology, North Dakota State University, Fargo, ND. "Status of Biological Control in North Dakota." (No report submitted)

I. Robert Nowierski, William Bruckart, and G. Defago, Dept. of Entomology, Montana State University, Bozeman, MT. "Status of Research on European Plant Pathogens of Leafy Spurge."

J. James G. Hoch, L. J. Littlefield, R. M. Hosford, Jr., and Glen D. Statler, Dept. of Plant Pathology, North Dakota State University, Fargo, ND. "Continued Studies of Plant Pathogenic Fungi for Biocontrol of Leafy Spurge in North Dakota."

K. S. F. Forsyth and Peter Harris, Agriculture Canada, Regina Saskatchewan, Canada. "Biological Control of Leafy Spurge: Stress Factors, Selection and Evaluation of Natural Enemies."

L. Robert W. Pemberton and Gerald Johnson, USDA-ARS, Biological Control of Weeds Laboratory, Albany, CA. "Two New Insects (*Dasineura capitigena* and *Aphthona flava*) for Leafy Spurge Control in the United States."

M. Robert M. Nowierski, Dept. of Entomology, Montana State University, Bozeman, MT. "Status of the Spurge Hawkmoth – Potential for Redistribution in 1985."

N. Gary L. Cunningham, APHIS-PPQ, Hyattsville, MD. "Implementary Biological Control - How the Animal and Plant Health Inspection Service May Help."

O. Jim Torell and John O. Evans, Utah State University. "Bio-Chemical Studies of the *Euphorbia esula* Complex."

P. Mark A. Ferrell, H. P. Alley, and R. E. Vore, University of Wyoming, Laramie, WY. "Evaluation of Spring vs. Fall Original/Retreatment Combinations as Affecting Leafy Spurge Live Shoot Regrowth."

Q. Heneidi Ganal, Mark A. Ferrell, and S. D. Miller, University of Wyoming, Laramie, WY. "Evaluation of 2,4-D LVE as a Setup Treatment for Low Rates of Picloram (Tordon 22K) for Leafy Spurge Control."

R. Tom D. Whitson, University of Wyoming, Laramie, WY. "Comparative Treatments of Fluroxypyr, Dicamba, and Picloram for Leafy Spurge Control."

II. Theme presentations:
"The payoff from 5 years of leafy spurge research."

A. James Welsh, Director of the Montana Agricultural Experiment Station, Bozeman, MT. Keynote Address - "The Payoff from 5 Years of Leafy Spurge Research."

B. Celestine Lacey, Charles Egan, W. Pearson, and P. K. Fay, Dept. of Plant and Soil Science, Montana State University, Bozeman, MT. "Bounty Programs - An Effective Weed Education Tool."

C. Wayne Pearson, Weed Supervisor, Columbus, MT. "The Spurge Program in Stillwater County, MT."

D. Doug Johnson, Weed Supervisor, Great Falls, MT. "Controlling Spurge Using All-Terrain Vehicles."

E. Mary B. McKone, Dow Chemical Co., Billings, MT. "Management Guidelines - Rangeland Weeds."

F. Harold Alley, Prof. Emeritus, University of Wyoming, Laramie. "Controlling Spurge with Tordon."

G. Rodney G. Lym and Calvin G. Messersmith, Dept. of Agronomy, North Dakota State University, Fargo, ND. "Economical Control of Leafy Spurge."

H. Michael E. Foley, Dept. of Plant and Soil Science, Montana State University, Bozeman, MT. "Is There a Payoff for Basic Research on Leafy Spurge?"

I. Robert Nowierski, Dept. of Entomology, Montana State University, Bozeman, MT. "Prospects for Biological Control of Leafy Spurge."

J. Dean Peterson, Rancher, Judith Gap, MT. “A Practical and Profitable Way of Controlling Leafy Spurge.”

III. Research group discussion

A. Chemical Control Group, Summary by Tom Whitson

B. Plant Physiology Group, Summary by Dr. M. E. Foley

C. Biological and Taxonomy Group (No summary provided)

IV. Research summaries for 1985

A. Wyoming - (Blue paper)

B. North Dakota - (Yellow paper)