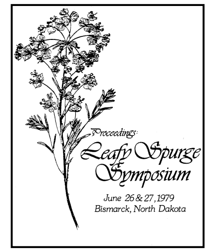
Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. i-iii.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.



Preface/Executive summary
Leafy Spurge Symposium

Preface

On June 26 and 27, 1979, about 125 educators, scientists, land managers, farmers, ranchers, legislators and concerned citizens met in Bismarck, North Dakota, to discuss the status of the noxious weed, leafy spurge. The Steering Committee who created the symposium did so in response to widely expressed concern over the advance of leafy spurge.

The symposium was designed with the following five objectives in mind:

- Assess and review the magnitude of the leafy spurge problem and its social and economic impacts.
- Become aware of completed and ongoing research on leafy spurge management.
- Identify needed basic and applied research to manage leafy spurge.
- Determine how various agencies and organizations can coordinate their work on needed basic and applied research to manage leafy spurge.
- Establish a knowledge base for future educational programs concerning management of leafy spurge on public and private lands.

The symposium began with the presentation of technical papers on: The Plant Leafy Spurge; The Magnitude of the Leafy Spurge Problem; Social and Economic Impacts of the Leafy Spurge Problem on Public Lands; Social and Economic Impacts of the Leafy Spurge Problem on Private Lands; Biological Control of Leafy Spurge; Cultural (Mechanical) Control of Leafy Spurge; Chemical Control of Leafy Spurge. These papers are presented in their entirety in this document, immediately following the executive summary.

Following the presentation of technical papers, symposium participants gathered in small groups for detailed discussion of the topics presented. These workshop sessions dealt with the topics of: The Plant Leafy Spurge; Social and Economic Impacts of the Leafy Spurge Problem; Biological Control of Leafy Spurge; Cultural (Mechanical) Control of Leafy Spurge; Chemical Control of Leafy Spurge. The results of the small group discussions were presented in summary form at the closing session of the symposium. These summaries constitute the latter part of the symposium proceedings. In addition, comments were invited from individual symposium participants. Those comments which have been received are included in the addendum section of the proceedings.

Through this approach, the Steering Committee hoped that symposium participants would be able to constructively address the first four symposium objectives. If successful, the published proceedings of the entire symposium would then provide the basis for the fifth objective, i.e., establish a knowledge base for future educational programs concerning management of leafy spurge on public and private lands. If this document provides such a base, then the entire symposium will have been well worth while.

As a direct response to the expressed concern over leafy spurge, funds allocated to the North Dakota Agricultural Experiment Station have been designated for an increased research program on the weed. Also, a project request will be submitted to the Old West Regional Commission. This request will involve all five OWRC states.

The Steering Committee expresses their sincere appreciation to all of the speakers for their efforts in preparing and presenting the technical papers. We also appreciate the excellent and deep involvement of all participants in the workshop sessions and the closing summary.

The challenge which remains is to take the results of this conference and establish action programs in research and education for more effective management of the noxious weed, leafy spurge.

Edwin H. Amend, Chairman
Associate Director
Cooperative Extension

Executive summary
Leafy Spurge Symposium

Leafy spurge is an introduced weed whose populations have greatly increased in North America involving over 2 1/2 million acres. The weed infestations continue to increase at an alarming rate. Farmers, ranchers and land managers are spending tremendous sums of money each year to control the weed with only limited success.

Experience has shown that leafy spurge is not a problem on cultivated lands. Repeated tillage operations, crop rotations and use of herbicides control the weed in the cultivated lands. The weed may become more important as the no-tillage farming concept becomes more widespread. Leafy spurge becomes a greater problem on rangelands and in disturbed areas.

Leafy spurge has quite a socio-economic impact on people. In contrast to its rapid spread in the U.S., in Canada, government assistance programs for leafy spurge control has kept the weed from spreading and the extent of infestation hasn't changed markedly in 20 years. , In order to have an effective program in the U.S., farmers, ranchers and other land managers will need financial assistance and/or incentives to control leafy spurge. Land owners and the general public need to be educated on the severity of the problem, the socio-economic impact and what can be done about the problem. An increased effort should be made to educate those involved on current control technology. Additionally, new and more effective control technology is urgently needed. Both of these efforts will require time, people and additional money.

Presently we need an up-to-date inventory of the actual leafy spurge infestation. This would include who controls the infested land. Incentives must be available to insure a concerted effort of all land owners to control leafy spurge.

Research needs on the leafy spurge problem include: an up-to-date review of leafy spurge literature and research, study of the taxonomy of the leafy spurge complex, study of the ecology of leafy spurge, study of the physiology, especially concerning the dormancy and viability of buds, study of the biological control, and study of the chemical control, especially new application techniques and new chemicals.

It was the consensus of the people in Bismarck that there should be an overall Steering Committee to oversee the research to insure a concerted and coordinated effort on the leafy spurge problem.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 1-7a.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

The leafy spurge plant – (*Euphorbia esula* L.)

DR. CALVIN G. MESSERSMITH

Associate Professor in Agronomy, North Dakota State University

Leafy spurge (*Euphorbia esula* L.) is a dicotyledonous herbaceous deep-rooted perennial of the spurge (*Euphorbiaceae*) family. It is a difficult weed to control so the weed has spread steadily since its introduction. Leafy spurge infestations are considered serious enough to be declared a noxious weed by law in at least 19 states (13).

Leafy spurge is widespread in continental Europe as far south as central Spain, Italy, and the Balkans, extending eastward through central Russia into Siberia (21). It is significant that leafy spurge apparently isn't a serious weed problem in this area of origin. The earliest report of the weed in the United States is a herbarium specimen collected in 1827 in Massachusetts, and leafy spurge has been known in North Dakota since 1909 (9). The weed was not recognized in western Canada until the early part of the 20th century (37). Early, reports in Manitoba were from Russian Mennonite settlements where seed may have been brought with them from Russia (9). The greatest abundance of the weed now is in the northern Great Plains of the United States and the Prairie Provinces of Canada.

Inflorescence

The most conspicuous feature of leafy spurge is the yellowish-green flower-like clusters. The flowers are borne on a terminal umbel or on lateral branches near the top of the stem. Each pedicel of the umbel bears a cyathium (producing both staminate and pistillate flowers) from which 2 opposite branches arise. Each of these in turn produces a cyathium, and the process is repeated until the single, original floral branch has divided into 8 to 16,branchlets (37). The yellowish-green bracts are the colorful parts of the plant, but are not true flower parts.

The true flower parts are surrounded by a cup-like involucre of the cyathium. There is no calynx or corolla (9). The involucre surrounds a flower cluster of 15 to 20 stalked, staminate flowers, each consisting of a single stamen, and a single-stalked pistillate flower (37). The stigmas of the pistil open and become receptive to pollen from 1 to 3 days after emergence of the female flower. From 3 to 8 days later, the glands of the cyathium begin secreting nectar. Then, inversion of the female flower occurs by elongation of the pedicel and the appearance of 1 or 2 male flowers. On the day following inversion, from 2 to 5 male flowers appear, reaching a total of 11 to 20 male flowers within 3 days.

Mature pollen is found on the anthers from 24 to 48 hours after emergence of thy male flower, and becomes orange and sticky when ripe. Pollination appears to be accomplished almost entirely by insects. Ants, bees, flies, and mosquitoes have been observed to feed on the nectar, and may be responsible for much of the pollination (37). The mechanism of pollination in leafy spurge is such as to minimize self-pollination.

The fruit develops from a superior, 3-celled ovary, and dehisces explosively usually along the line of union of the carpels. Nearly 50% of the fruits produce only one mature seed, about 35% produce 2 seeds, and only 15 to 20% produce 3 seeds (9).

Individual seed stalks produce from 10 to 50 fruits, so there are 25 to 150 seeds per stalk. The date of first appearance of the inflorescence varies between early and late May (37). Flowering generally ceases in terminal inflorescences between the end of June and the middle of July. The development and maturation of the seed extends approximately 30 days beyond the appearance of the last flower.

Seeds

Seeds are silvery gray to light gray tinged with purple. There is a prominent yellow-colored, pointed caruncle at the narrow end and a brown line extends from the caruncle to the opposite end (9, 13). Seeds go through several color changes during development from yellow through orange and brown to gray at maturity (4, 40). Seeds are viable by the brown stage which occurs 10 to 13 days after fertilization depending upon seasonal conditions. Thus, control to prevent viable seed production must be done before seeds have turned brown.

Seed germination is most rapid at alternating 20 and 30 C, followed by constant 30 C and constant 20 C (9). Field germination of seeds in the spring follows several days of air temperatures of 26 to 28 C (37). The majority of the seeds germinate in the spring, but some seeds fill germinate throughout the growing season. Under favorable conditions, 99% of the seeds will have germinated within 2 years and the remainder either germinated or deteriorated within 5 years.

The explosive force of the mature capsule hurls the seed up to 15 feet and distributes them uniformly (9). Wild and domestic animals, birds, and insects are agents of seed dispersal. The activity of birds as disseminators of seeds of leafy spurge has been suggested because of frequent feeding, particularly by mourning doves (37). No viable seeds have been found in the digestive tracts of birds, but seeds may be dropped during regurgitation to feed the young. Seeds also move in flowing water, on machinery, and in hay.

Seedlings

The plant emerges by elongation of the hypocotyl, and the cotyledons function as the first leaves. The first true leaves generally develop within 6 to 10 days after emergence (37). The first 2 leaves are opposite, but the remainder are distinctly alternate.

Seedlings develop perennial characteristics rather quickly. Of 22 seedlings in the 6-leaf stage which were cut 0.5 inch below the soil surface, 11 produced new shoots (37). And all of the seedlings survived when severed in the 10-leaf stage at a depth of 0.5 inch. Buds on the hypocotyl may be either exogenous (arising from thy cortex) or endogenous (arising on some part of the stele) (26). The hypocotylary buds are formed spontaneously in leafy spurge and are inhibited by apical dominance. Decapitation of seedlings results in development of shoots on the hypocotyl.

Seedling survival generally is low especially with competition (9, 37). Selleck *et al*. (37) reported 2800 seedlings per square meter on May 27, 1951 in a natural infestation, but 82% of the seedlings had died by September 12.

Stem and leaves

Stems usually are erect and 16 to 32 inches high. Stems generally are unbranched except for the inflorescence, but axillary buds develop frequently when the stem tip has been injured. The stems become woody toward the base, so the dead stem remains standing for 1 or more years. Stems are pale green in summer, but become red in the fall.

The structure of the mature stem is characterized by a continuous, relatively wide cylinder of xylem, resembling that of a. woody plant (9) The phloem is inconspicuous, as in many plants containing latex.

Leaves are linear-lanceolate to ovate, broader above the middle, tapering to the base, sessile, margins entire or slightly sinuate, leaves thin, and not glossy (21). Leaves are bluish-green in color and weakly veined except for the midrib. The epidermis has a fairly thick layer of cutin, especially toward the margins of the leaf (9). The stomata are numerous on both surfaces, with more on the lower surface, and are sunken below the surface.

Roots

The most important part of the plant in terms of leafy spurge control is the root system, and associated vegetative buds. There are numerous coarse roots that occupy a large volume of soil. The roots are woody and tough in structure with numerous buds. New shoots are produced readily from small pieces of roots. It has been demonstrated that no roots died within the first 6 years during the development of plants (37).

The roots have a thick, tough stele and a thick corky bark. Roots are most abundant in the upper foot of soil, but some roots normally penetrate deeper into the soil. Some roots penetrate 15 feet (2). Roots in the upper foot of soil usually are brown and woody and can be 0.5 inch in diameter (9). Roots become more yellowish in color and diameters decrease with depth, frequently becoming only 1/16-inch diameter. It was observed that one seedling of leafy spurge increased in size to occupy an area of soil 24 feet in diameter in 4 years (6). Even greater rates of spread were recorded for plants established by planting pieces of roots.

All horizontal underground structures are roots and not rhizomes (24). All underground stem tissue examined in leafy spurge was vertical and a product of adventitious bud development from horizontal, vertical, and oblique roots. There are two types of roots produced on plants (32,35). ‘‘Long’’ roots arise from the vigorous primary root of the seedling, and have extensive longitudinal growth and considerable cambial activity. ‘‘Short’’ roots arise from long roots, but have limited growth and no cambial activity. Long roots give rise to lateral long roots and shoot buds but the origin of these structures is delayed until cambial activity has started. Short roots do not give rise to shoot buds.

Roots of leafy spurge have great capacity to produce new shoots from various depths. Shoots at all locations were able to penetrate 2 feet of soil within 12 months, and some shoots were able to emerge through 3 feet of soil (8). Following regrowth of shoots from 1 and 2 feet deep, new crowns were formed near the soil surface, from which regrowth occurred the following year. Roots had the ability to produce vegetative shoots for 5 successive years from a depth of 3 feet after the major portion of the root system had been removed.

Vegetative buds

Buds occur on both the roots and underground portion of shoots. The maximum depth at which buds occur on plants varies from 12 to 68 inches depending on the plant (7). The average number of buds per root in excavations was 35 to 272 buds in different groups. The number of vegetative buds tends to be greatest just below the soil surface and to decrease with increasing depth. The number of vegetative buds at each depth seems to be directly related to the weight of root material in each layer.

Roots have vegetative buds on both the horizontal and vertical portions of the long roots. New long roots do not develop buds until cambial activity has begun, while older roots develop additional buds without any particular pattern (32). Only a few of the root buds develop into shoots. Shoots first develop on horizontal roots of an intact root system at some distance from the parent root, commonly at or near the point of vertical turning. Later additional shoots nay arise on the horizontal root closer to the parent root.

The underground system of leafy spurge is composed predominately of roots, but buds which develop into shoots have an underground portion which is persistent after the aerial portions have died back (32). Buds are formed on these underground stems both in the axils of the scale-like leaves and adventitiously elsewhere. A number of stem buds frequently develop into shoots forming a crown of shoots after several years. The underground stems are vertical and do not contribute directly to the spread of the plant, but they do serve an important function in perennation. Moreover, they give rise to adventitious roots, some of which are spreading long roots that contribute to the vegetative spread of the plant.

Latex

Latex is present throughout the plant from the root to the shoot (2). Injury to any part of the plant will result in immediate flow of the white, sticky latex to seal the wound. Apparently the latex tubes originate as one cell beginning in the embryo (9). Characteristic cigar-shaped starch grains are found in the latex.

Poisonous properties

Leafy spurge contains a toxic substance apparently in the latex. The toxin when taken internally is an irritant, emetic and purgative. It causes scours and weakness in cattle, and may result in death (37). The toxin has produced inflammation and loss of hair on the feet of horses from freshly mowed stubble during haying (12), and has caused mortality of sheep in Alberta (11). Animals will eat the dried plants in hay, but usually avoid eating growing plants (13).

Allelopathy

Aqueous extracts of fresh and dried leafy spurge foliage inhibited growth of pea and wheat seedlings, while increased concentrations inhibited coleoptile growth and germination of wheat (17). Extracts of young spurge plants were more effective than similar extracts of older plants, and extracts of leaves were more inhibitory than stem extracts (15). The paucity of forbs in patches of leafy spurge, even when bare ground is visible between shoots, suggests that this species exerts antibiotic effects on other plants (36).

Reductions in frequency and density of quackgrass and common ragweed were noted where leafy spurge had high densities in the field (39). Field soil samples taken from areas of moderate and high leafy spurge densities inhibited tomatoes in the greenhouse. It was postulated that leafy spurge exhibits allelopathic characteristics which may result from the incorporation of dead or decaying plant material in soil.

Physiology

Starch grains fill the parenchyma cells of the cortex of the root (9). Also, starch grains are present in the latex of the plant. The abundance of stored starch plus the extensive size of the root system provides large quantities of food reserves for survival of the plant. Sucrose and glucose were the predominant free sugars, while lesser amounts of fructose were present (16). Boot carbohydrate content changes substantially with sampling date within a year and from year to year (5). Generally, the leafy spurge root carbohydrate content is lowest when seed production is nearly complete and highest in the early spring or late fall.

Gibberellic acid stimulates growth of emerged dormant leafy spurge buds, causes branching and new shoot development on old shoots, and stimulates the emergence of new buds (38). The effects of the gibberellic acid stimulant were similar to those associated with the removal of apical dominance, but the growth rate was several times that obtained when topgrowth was removed.

When seedlings of leafy spurge were grown at a low nitrogen level, the growth of the lateral buds on the shoot was completely arrested by apical dominance, while the buds on the roots were inhibited but showed considerably greater activity than the shoot buds (18). The number of lateral buds per unit length of the parent roots and the number of shoot buds on the root system were both considerably greater at the higher nitrogen levels (19).

Genetic variability

Wide differences in the number of buds on roots and their distribution in soil have been reported (7). This indicates that differences in habitat and possibly genetic stock were responsible for the wide variation encountered. Certain isolated infestations of leafy spurge (presumably of 1 clone) in Saskatchewan have been found to produce female flamers only, but the dioecious character is rare in this species (37).

Bibliography

This list of citations includes many pertinent articles about the leafy spurge plant, and not all of these articles are cited in the paper. Three articles that provide a good review of the general plant characteristics are Bakke (2), Hanson and Rudd (9), and Selleck *et al*. (37).

1. Arny, A.C. 1932. Variations in organic reserves in underground parts of five perennial weeds from late May to November. Minnesota Agr. Exp. Sta. Tech. Bull. 84.

2. Bakke, A.L. 1936. Leafy spurge, *Euphorbia esula* L. Iowa Agr. Exp. Sta. Res. Bull. 198.

3. Bakshi, T.S. and R.T. Coupland. 1959. An anatomical study of the subterranean organs of *Euphorbia esula* in relation to its control. Can. J. Bot. 37:613-620.

4. Bybee, Thomas A. 1976. Factors affecting leafy spurge reestablishment. M.S. Thesis, North Dakota State Univ., Fargo. 54 p.

5. Bybee, Thomas A. 1919. Factors affecting leafy spurge control including leafy spurge reestablishment, herbicide translocation and root carbohydrates. Ph.D. Thesis, North Dakota State Univ., Fargo. 78 p.

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

7. Coupland, Robert T., and Jack F. Alex. 1955. Distribution of vegetative buds on the underground parts of leafy spurge (*Euphorbia esula* L.). Can. J. Agr. Sci. 35:76-82.

8. Coupland, Robert T., G.W. Selleck, and J.F. Alex. 1955. The reproductive capacity of vegetative buds on the underground parts of leafy spurge (*Euphorbia esula* L.). Can. J. Agr. Sci. 35:477-484.

9. Hanson, H.C. and V.E. Rudd. 1933. Leafy spurge--Its life history and habits. N.D. Agr. Exp. Sta. Bull. 266.

10. Ho, T.W.M. and M.V.S. Raju. 1972. Developmental studies on leafy spurge (*Euphorbia esula* L.). Histology of the adventitious shoot apex. Can. J. Bot. 50:635-641.

11. Johnston, A. and R.W. Peake. 1960. Effect of selective grazing by sheep on the control of leafy spurge (*Euphorbia esula* L.). J. Range Management 13:192-195.

12. Kingsbury, John M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall, Inc., Englewood Cliffs, N.J.

13. Krockmal, Arnold. 1952. Seeds of weedy *Euphorbia* species and their identification. Weeds 1:243-255.

14. Lee, T.T. and A.N. Stanatt. 1972. Growth substance requirements and major lipid constituents of tissue cultures of *Euphorbia esula* and *E. cyparissias*. Can. J. Bot. 50:723-725.

15. LeTourneau, D., G.D. Farles, and M.G. Heggeness. 1956. The effect of aqueous extracts of plant tissue on germination of seeds and growth of seedlings. Weeds 4:363-368.

16. LeTourneau, Duane and H.G. Heggeness. 1956. A note on the sugars and amino acids of leafy spurge (*Euphorbia esula* L.). Weeds 4:275-277.

17. LeTourneau, Duane and H.G. Heggeness. 1957. Germination and growth inhibitors in leafy spurge foliage and quackgrass rhizomes. Weeds 5:12-19.

18. McIntyre, G.I. 1972. Developmental studies on *Euphorbia esula.* The influence of the nitrogen supply on the correlative inhibition of root bud activity. Can. J. Bot. 50:949-956.

19. McIntyre, G.I. and M.V.S. Raju. 1967. Developmental studies on *Euphorbia esula*. Some effects of the nitrogen supply on the growth and development of the seedling. Can. J. Bot. 45:975-984.

20. Monson, Warren G. and Frank S. Davis. 1964. Dormancy in western ironweed and leafy spurge. Weeds 12:238-239.

21. Moore, R.J. 1958. Cytotaxonomy of *Euphorbia esula* in Canada and its hybrid with *Euphorbia cyparassias*. Can. J. Bot. 36:547-559.

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

23. Morton, C.V. 1937. The current name of the leafy spurge. Rhodia 39:49-50.

24. Meyers, Gerald A., Charles A. Beasley, and Lyle A. Derscheid. 1964. Anatomical studies of *Euphorbia esula* L. Weeds 12:291-295.

25. Raju, M.V.S. 1968. Developmental studies on leafy spurge (*Euphorbia esula*. L.) Apices of seedling and adventitious shoots. Can. J. Bot. 46:1529-1532.

26. Raju, M.V.S. 1975 a. Experimental studies on leafy spurge (*Euphorbia esula* L.). I. Ontogeny and distribution of buds and shoots on the hypocotyl. Bot. Gaz. 136:254-261.

27. Raju, &V.S. 1975 b. Experimental studies on leafy spurge (*Euphorbia esula* L.). II. Starch distribution and vasculature in relation to apical dominance. Bot. Gaz.136:262-268.

28. Raju, M.V.S., R.T. Coupland, and T.A. Steeves. 1966. On the occurrence of root buds on the perennial plants in Saskatchewan. Can. J. Bot. 44:33-37.

29. Raju, H.V.S. and T.W.M. Ho. 1973. Developmental studies on leafy spurge (*Euphorbia esula* L.). Histochemical and auto radiographic studies of the adventitious shoot apices. Can. J. Bot. 51:211-219.

30. Raju, M.V.S. and William N. Marchuk. 1977. Experimental studies on leafy spurge (*Euphorbia esula* L.). III. Xylem development in relation to the hypocotylary bud growth. Bot. Gaz. 138:305-311.

31. Raju, M.V.S., Patricia L. Polowick, and W.N. Harchuk. 1978. Experimental studies on leafy spurge (*Euphorbia esula* L.). IV. Cytohistological changes in the cotyledonary shoots following decapitation. Can. J. Bot. 56:1409-1415.

32. Raju, M.V.S., T.A. Steeves, and R.T. Coupland. 1963. Developmental studies on *Euphorbia esula*. Morphology of the root system. Can. J. Bot. 41:579-589.

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

34. Raju, M.V.S., T.A. Steeves, and J.M. Maze. 1976. Developmental studies on *Euphorbia esula* L. Seasonal variation in the apices of long roots. Can. J. Bot. 54:605-610.

35. Raju, M.V.S., T.A. Steeves, and J.M. Naylor. 1964. Developmental studies on *Euphorbia esula* L. apices of long and short roots. Can. J. Bot. 42:1615-1628.

36. Selleck, G.W. 1972. The antibiotic effects of plants in laboratory and field. Weed Sci. 20:189-194.

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

38. Shafer, Neal E. and Warren G. Monson. 1958. The role of gibberellic acid in overcoming bud dormancy in perennial weeds. I. Leafy spurge (*Euphorbia esula* L.) and ironweed (*Vernonia Baldwini* Torr.) Weeds 6:172-178.

39. Steenhagen, D.A. and R.L. Zimdahl. 1979. Allelopathy of leafy spurge. Weed Sci. 27:1-3.

40. Wicks, G.A. and Lyle A. Derscheid. 1964. Leafy spurge seed maturation. Weeds 12:175-176.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 8-15.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

The leafy spurge problem

DANIEL L. NOBLE, PAUL H. DUNN and LLOYD A. ANDRES

Research Ecologist, Research Entomologist and Supervisory Research Entomologist, respectively. Dr. Noble is with the U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Work Unit at Rapid City in cooperation with South Dakota School of Mines and Technology; station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Mr. Dunn and Dr. Andres are at the Biological Control of Weeds Laboratory, U.S.D.A., Science and Education Administration, Agric. Research, Albany, California.

Introduction

A plant pest as complex and tenacious as leafy spurge, infesting nearly 2½ million acres in North America, with a conservative 1978 economic impact in the United States of $10.5 million[1], has reached a serious, if not critical level. The problem is most severe on rangelands, pastures, tree belts, parks, waterways and roadsides. Even on cultivated cropland, where leafy spurge has been controlled, it can reduce crop yields 10% to 100% (Derscheid and Wrage 1972). On rangelands, the weed displaces useful forage and if unchecked will invade and become dominant on pastures and ranges in excellent condition. Leafy spurge is a poisonous plant which produces an irritant causing dermatitis to man and animals (Kingsbury 1964). Cattle will not eat leafy spurge unless forced to by poor range conditions or when fed weedy hay. Sheep will graze small plants with no apparent ill effects but large plants are toxic (Johnston and Peake 1960).

Distribution

The Caucasus region of the Soviet Union is the origin for leafy spurge (Croizat 1945). Its distribution in Eurasia extends across Europe from Norway, England and Portugal in the west, through Asia Minor--Turkey, Iran, Afghanistan and Pakistan. It occurs as far north as Siberia, and east into China where it is considered an introduced species (Bakke 1936, Prokhanov 1949).

[1] Personal communication with Dr. Claude H. Schmidt, Area Director, USDA-SEA-AR, Fargo, North Dakota. December, 1978.

Leafy spurge was reported in Massachusetts in 1827 (Britton 1921). In 1933, Hansen and Budd reported the plant in 20 states, extending from New England across the northern tier of states to Washington, with a concentration center in Minnesota, North Dakota and eastern South Dakota.

Moore (1958) showed leafy spurge well distributed in western Canada, and Harris and Alex (1971) reported leafy spurge in every Canadian province except Newfoundland. Reed and Hughes (1970) described its distribution similar to Hansen and Budd (1933), with the plant in northern Missouri, Wyoming, Nevada, northeastern California and Oregon. They show the center of concentration shifting slightly mast to include eastern Montana, most of South Dakota, northern Nebraska and the northeast corner of Wyoming. Dunn (1979) reports leafy spurge in 25 states with 451 infested counties (Table 1).

Table 1. Distribution of leafy spurge in the 48 contiguous states. (Dunn 1979).

	Number of Counties:	Levels of Infestation[1]		
		A	B	C
Arizona	1			1
California	2			2
Colorado	8	6	2	
Delaware	2		1	1
Idaho	28	5	12	11
Illinois	3			3
Iowa	10			10
Kansas	4			4
Maine	1		1	
Michigan	11			11
Minnesota	80	5	29	46
Missouri	1			1
Montana	54	28	19	7
Nebraska	54	22	21	11
Nevada				3
New York				
North Dakota	52	41	10	1
Oregon			5	1
Pennsylvania,	Z7			27
South Dakota	47	24	16	~7
Utah	10	1	6	3
Washington	6	1	1	4
West Virginia	2,1			2
Wisconsin	7	1	5	1
Wyoming	21	8	11	2
Totals:	451	142	139	170

A >50-0 acres; B 25 to 500 acres; C <25 acres.

The leafy spurge concentration area, estimated to cover 80% to 85% of the problem in North America, now covers all or parts of nine states and five Canadian provinces. The area is defined in a 1,200-mile diameter circle centered at 106° W. Long. and 48° N. Lat., near Wolf Point, Mont. (Fig. 1).

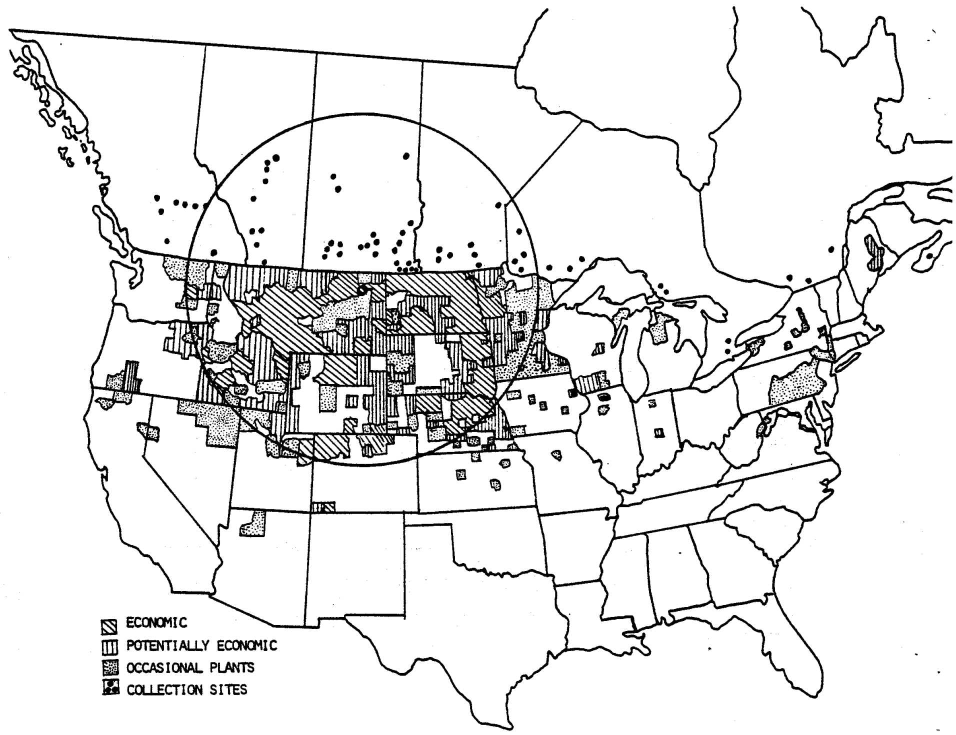


Figure 1. A concentration area covering approximately 90% of leafy spurge in North America is defined in a 1,200-mile diameter circle centered near Wolf Point, Mont.–106° W. Long., 48° N. Lat. (Dunn 1979, Moore 1958, Moore and Frankton 1969, Selleck *et al*., 1962).

Infestation

About 2 1/2 million acres in North America are estimated to be infested with leafy spurge. In the United States, Minnesota has highest infestation at 800,000 acres followed by North Dakota and Montana with 600,000 and 543,000 acres, respectively. The Canadian problem is estimated to be comparable to Nebraska.

The degree or level of infestation and infested net acres are important in defining the spurge problem. Information is seriously lacking in both areas. Dunn (1979) reported infested counties according to those with

500 acres, 25 to 500 acres, and >25 acres. By giving counties with >500 acres a factor of 20, those with 25 to 500 acres a factor of 10 and those with 25 acres a factor of 1, a simple estimate is possible for the degree of infestation for each state.

Diversity

The name leafy spurge encompasses a diversity of taxonomic and biological plant types which greatly confound the problem of spurge control. Indicative of this diversity is a statement by Croizat who in 1945 wrote "Long years may elapse before it proves feasible even to begin the work of basic revision necessary to put the classification of *Euphorbia esula* and its vast alliance on a sound taxonomic and nomenclature footing.'' To further illustrate this point, the following list of taxa have been linked with leafy spurge:

Euphorbia esula L.
E. *virgata* Waldst. and Kit
E. *virgata-esula* Schur.
E. *pseudoesula* Schur.
E. *virgata* var. *orientalis* Boiss.
E. *virgata* var. *latifolia* Schur.
E. *lucida* Waldst. and Kit
E. *lucida* var. *androsaemifolia* Koch
E. *pseudolucida* Schur.
E. *uralensis* Fisch. ex Link
E. *intercedens* Podp (*E. intercedens* Pax)
E. p*odperae* Croiz.

This nomenclature headache presents serious problems for researchers and managers as they use the literature to determine what is known about leafy spurge and its control and whether the results or data from one area are applicable to their specific leafy spurge problems. The range of biotypes and phenotypes is also creating unexpected problems in the development of host-specific biological control organisms. Organisms effective on one type of spurge often will not attack "other" spurges. Also, this broad plant-ecological diversity helps to explain, in part, discrepancies in the literature as to the effectiveness of certain control measures (i.e., varieties of leafy spurge with varying anatomy, physiology, and biochemistry associated with a range of environmental factors, appear to respond differently to the same control measures).

To further complicate this diversity problem, a hybrid of leafy spurge and cypress or graveyard spurge (*E. cyparissias* L.) was collected in Ontario, Canada, in 1962 (Moore and Frankton 1969). Cypress spurge is a low growing perennial that is native to Europe and was brought to this country as an ornamental (Stucky and Pearson 1973). It has been reported across Canada from Nova Scotia to British Columbia (Moore and Lindsay 1953). Dunn (1979) lists cypress spurge in 22 states and 220 counties from New England to Washington and south to Kansas and Arkansas.

The common variety of cypress spurge is a sterile male diploid that vegetatively propagates through an efficient rhizominous root system. While difficult to eradicate, this diploid form has a slow rate of spread. However, the existence of a fertile tetraploid that propagates both sexually and asexually and hybridizes with leafy spurge compounds the problem.

In 1952 at Braeside, near Ottawa, Canada, a 9-square-mile infestation of the fertile tetraploid was reported (Harris and Alex 1971); and, at this time the infestation covers a 36-square-mile area.[2] This tetraploid phenotype is known to exist in New York and Massachusetts and probably occurs in several other states. (Dunn 1979).

The percentage or degree of the leafy spurge problem and number of infested acres per state is estimated at:

	Percent of Total Problem	Estimated Infestation (acres)
North Dakota	21	6000,000[a]
Montana	17	543,000[b]
Nebraska	15	105,000[c]
South Dakota	15	60,000[d]
Minnesota	10	800,000[e]
Idaho	6	35,000[g]
Wyoming	5	30,000[g]
Other States	11	100,000[h]
(Utah and Colorado 5%; 22,000 acres)		
Total	(100%)	2,273,000
Canada[i]		125,000
	Total	2,398,000

Average estimates obtained from:
[a]Dr. Larry Mitich. *In*: "Takes Persistence to Eliminate Leafy Spurge.'' Bar North, June 1973, p. 26, and "Leafy Spurge – A Tough Weed but it can be Beaten", Crops and Soils, April-May 1972, p. 25-26.
[b]Information from the State A.S.C.S. Office, 1979.
[c]Personal communication with Dr. Mel McCarty, SEA-AR, University of Nebraska. May 1979.
[d]Publication by Lyle A. Derscheid and Leon J. Wrage. 1972. (See Literature cited.)
[e]Personal communication with Dr. Oliver E. Strand, Dept. Agron. and Plant Genetics, University of Minnesota. May 1979.
[f]Personal communication with Gene Ross, State Dept. Agric., Boise, Idaho. June 1979.
[g]Personal communication with George F. Hittle, State Dept. Agric., Cheyenne, Wyoming. May 1979.
[h]Personal communication with Dr. Eugene Heikes, Botany Dept., Colo. State University. May 1979; and Dr. Louis Jensen, Coop. Ext. Serv., Utah State University, June 1979.
[i]Personal communication with Dr. Peter Harris, June 1979.

Literature cited

1. Bakke, A. L. 1936. Leafy spurge, *Euphorbia esula* L. Iowa Res. Stn. Res. Bull. No. 189; 209-245.

2. Britton, N. L. 1921. The leafy spurge becoming a pest. J. N. Y. Bot. Gard. 22:73-75.

3. Derscheid, L. A., and L. J. Wrage. 1972. Leafy spurge. S. Dakota State Univ. Ext. FS 449, 4 p.

4. Croizat, L. 1945. *Euphorbia esula* in North America. Am. Midl. Nat. 33:231-243.

5. Dunn, P. H. 1979. The distribution of leafy spurge (*Euphorbia esula*) and other weedy spurges in the United States. Accepted for pub in *Weed Science*, May 9, 1979.

6. Hansen, H. C., and V. E. Rudd. 1933. Leafy spurge, life history and habitats. North Dakota Agric. Exp. Stn. Fargo, Bull. 266, p. 1-24.

[2] Personal communication with Dr. Peter Harris, Agriculture Canada, Regina, Saskatchewan. June 1979.

7. Harris, P. and J. Alex. 1971. *Euphorbia esula* L., leafy spurge and *E. cyparissias*, cypress spurge (*Euphorbaceae)* in biological control programmes against insects and weeds in Canada 1959-1968. Common. Inst. Biol. Control. Trinidad Tech. Common. No. 4:83-88.

8. Johnston, A., and R. W. Peake. 1960. Effect of selective grazing by sheep on the control of leafy spurge *(Euphorbia esula* L.). J. Range Manage. 12:192-195.

9. Kingsbury, J. M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall, New Jersey. 377 p.

10. Moore, R. J. 1958. The cytotaxonomy of *Euphorbia esula* in Canada and its hybrid with *Euphorbia cyparissias*. Can. J. Bot. 36:547-558.

11. Moore, R. J., and C. Frankton. 1969. *Euphorbia* x *pseudo-esula* (*E. cyparissias* x *E. esula*) in Canada. Can. Field Nat. 83:243-246.

12. Moore, R. J., and D. R. Lindsay. 1953. Fertility and polyploidy of *Euphorbia cyparissias* in Canada. Can. J. Bot. 31:152-163.

13. Prokhanov, J. I. 1949. Spurges--*Euphorbia* Flora U.S.S.R. Vol. XIV, p. 304-495.

14. Reed, C. F., and R. O. Hughes. 1970. Selected weeds of the United States. USDA Agric. Hand. 366, Washington, D.C.

15. Selleck, G. W., R. I. Coupland, and C. Frankton. 1962. Leafy spurge in Saskatchewan. Ecol. Monog. 32:1-29.

16. Stuckey, I. H., and J. L. Pearson. 1973. Cypress spurge. Univ. of R. I. Coop. Ext. Circ. No. 165, 4 p.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 16-20.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

Social and economic impacts of leafy spurge on public lands

D. C. MACINTYRE

Gentlemen, in my opinion we are in a war, and we're losing. It's a vegetative war and the enemy is a weed called leafy spurge. It is rapidly becoming the noxious weed Vietnam. In this war we are in, we need some new weapons. The ones we currently have are tactically sound and work in same situations, applied correctly. But strategically, they are not getting the job done.

For instance, in 1970 we had an estimated 2,700 acres of spurge infestation on the Custer. Our estimated acreage today is 9,000 acres of infestation.

In 1976, seeing the trend of this increase, we asked the Ranger Districts for a consolidated 10-year attack program. The program they proposed is represented by the following graph. It was keyed entirely to treatment with the standard available chemicals.

The chemicals the Forest uses are: 2,4-D, Tordon, Banvel, and Roundup–all the above applied by ground spray rigs or by hand sprays, and on an area-by-area prescription basis only.

Meanwhile, the spread of leafy spurge on the Forest is represented by the following curve.

Problems which the above proposed program posed for us:

A. Economic and program planning. With the above curves, we get poor benefit-cost ratios–programs that are hard to sell, just based on economic investment analysis alone. To the uninitiated observer it would appear that when we overlay the two curves, the more we treat, the more infestation we have.

B. Cumulative vegetational effects in hardwood draws, riparian zones, and rougher country are hard to quantify. For certain, we will have considerable effect on residual braodleaf vegetation and wildlife habitat in those areas where repeated treatment is required–which is most areas.

C. Yet state laws, county ordinances, and the nature of leafy spurge require weed control.

Estimated infestations on other Federal and Indian Lands in North Dakota and Montana:

The BIA in North and South Dakota reports 168,000 acres, and 2,400 acres on reservations in Wyoming and Montana. (BIA personal communication.)

The BLM estimates 14,700 acres in Montana alone. (BLM personal communication.)

The Custer National Forest as we have said, estimates 9,000 acres in Montana and North Dakota. There are 5 other National Forests in Montana estimating they have 3,000 acres.

Custer Forest Interaction with Forest Service Research:

So, in 1976 it looked like, to us, that we were indeed in a war that we were losing, and we needed more and better weapons for the long haul.

A. The Northern Regional Forester became convinced of the severity of our problem, and he, in turn, wrote a strong letter of appeal for help to the Director of the Rocky Mountain Research Station at Fort Collins. The Director sent some folks up from the Rapid City station to work with us; namely, Drs. Bjugstead and Noble, and their help has been invaluable.

B. Meanwhile, Bill Reilly, Judith Basin County Weed Supervisor, was at work in Montana, stirring up some meetings and interest in a new and strengthened attack on leafy spurge problems.

C. As a result of these activities, I think many of us came to a couple of conclusions at about the same time; namely, No. 1, that an individual or individual agency approach will not get us on top of our leafy spurge problems; and that No. 2, we really must have some concentrated research help on new weapons and techniques, and we must have it soon.

In the course of brainstorming what might be done to stimulate a strengthened, more integrated management and applied research attack on leafy spurge, we developed the simple matrix shown below.

There's nothing special or particularly inspired about this matrix. It just shows that a lot of people have concern, responsibilities about, and may have resources to attack the problem. In addition, the matrix proposes a conceptual framework on how we might go about pooling our resources and dividing up the work to be done in order to mount a new initiative on leafy spurge control, if we decide to, and had some help.

We've explained, a little, some of the dimensions of how the public land managers see the leafy spurge problem. Now, a few comments on how we see our neighbors' problems with spurge on deeded and state land.

First of all, we think they've got a hell of a lot more than we have in Montana and North Dakota, and I think Bill Reilly's figures will bear that out. (That's in no way to imply that ours is any less important to control. Indeed, some of the country our spurge occupies is among the most persistent and difficult to get at with conventional techniques and must be dealt with.)

Second, I think our State and Private neighbors are having a tougher and tougher time lining up the funds to do chemical control work. We are told the ASCS no longer can cost-share on spurge control, and have heard that many bankers in central Montana are increasingly reluctant to loan funds for this purpose.

Third, their problem is complicated by having different attitudes, varying capabilities, and different tools to attack the job within different counties and in different parts of the Northwest. There are 23 counties on the Custer, and I doubt any two have the same approach to leafy spurge.

In summary, I have only two conclusions and recommendations to make on what's needed to get us in ahead of this leafy spurge problem.

No. 1: We absolutely must have an accelerated multidimensional research program, and it must get underway soon. The longer we wait, the more the final solution is going to cost.

No. 2: We must develop a better working mechanism than we currently have for genuine, coordinated leafy spurge control and management. An urgent first step in this mechanism should be initiation of an improved uniform inventory procedure.

Table 1: Leafy spurge control programs, Custer National Forest, 1974-1986.

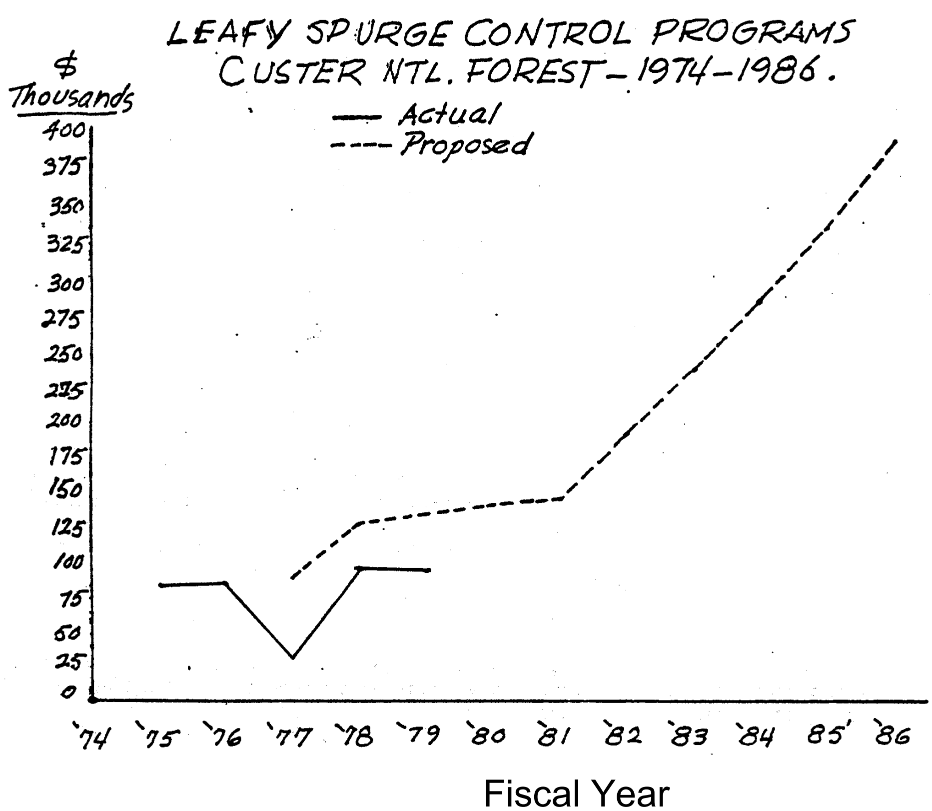


Table 2: Rate of leafy spurge increase, Custer National Forest.

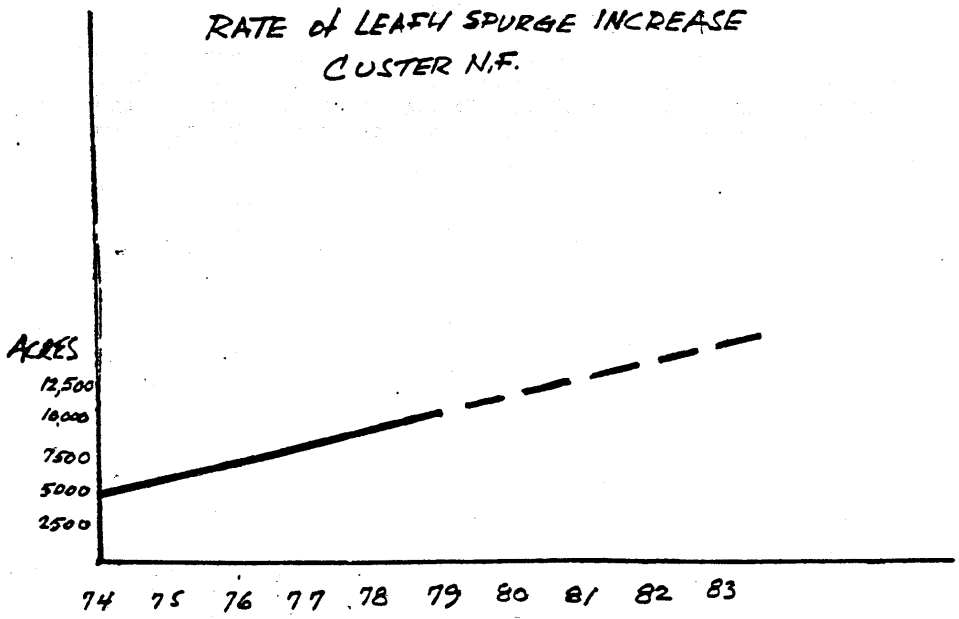


Table 3: Research extension need/resource matrix for leafy spurge.

RESEARCH-EXTENSION NEEDS → / CONCERNED-ENTITY-AGENCIES	INVENTORY	EXTENSION	RESEARCH: INSECTS	PATHOGENS	MECHANIC TREATMENT	GRAZING TREATMENT	FIRE	CHEMICALS	WILDLIFE CONSERVATION	
STATE EXPERIMENT STATIONS										
SEA· ARS.										
F.S. RES.										
CES										
NON-GOVERMENT										
Weed Boards										
Grazing Assoc.										
Industry										
BLM										
F.S.										
SCS										

RESEARCH-EXTENSION NEED/RESOURCE MATRIX-for LEAFY SPURGE

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 21-24.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

The social and economic impact of leafy spurge in Montana

WILLIAM REILLY and KIM R. KAUFMAN

Judith Basin County Weed Supervisor and Judith Basin County Extension Agent

The history of leafy spurge in Judith Basin County

Leafy spurge first appeared in the Judith Basin in 1929. It was introduced with Cossack Alfalfa seed onto a ranch in the foothills of the Little Belt Mountains. Very little attention was given to the plant at that time.

From this origin plus other sources of infestation, Judith Basin County now has an estimated 26,795 acres of leafy spurge.

This pattern is fairly representative of the state, where we now have an estimated 543,323 acres of leafy spurge.

The social impact of leafy spurge

The social impact of leafy spurge as well as other noxious weeds in Montana has led to a variety of conflicts.

One of the major conflicts has been trying to carry out the Montana Weed Law which states that "no noxious weed shall be allowed to go to seed."

This presents a challenge that few individuals or organizations are able to meet with the weed management tools we have available today.

With the type of terrain that exists in much of the foothill and mountain country where a majority of the leafy spurge exists, the sheer magnitude of the task creates an impossible situation.

Other conflicts exist as well, a common one being the "upstream landowner" who fails to control noxious weeds thus spreading the problem to his neighbors below him on the same watershed.

In Montana, there have been few court cases between landowners over the spread of noxious weeds, but as land prices continue to go up and more emphasis is put on production for farm and rangeland, the possibility of court cases will increase.

Conflicts between the railroads and adjacent landowners is a real and continuing problem. The landowners feel that it is a waste of time and money to spray noxious weeds if the railroads do not do the same and vice versa. In some areas, the railroads are doing an adequate job of controlling the weed problem and it is the landowners who are at fault.

Noxious weeds on state-owned land also presents a problem, both for the lessee of the land and the administrators of the land. Lessees run the risk of losing the land if the noxious weeds are not controlled, however, in many cases the cost of such measures seems to be prohibitive in respect to the return from the land in strict dollars and cents terns.

Weed districts are finding themselves in more and more of an enforcement role in trying to administer the Noxious Weed Law at the County level.

Weed Supervisors are many times the arbitrator in disputes that arise between landowners, between landowners and railroads and between highway departments and landowners.

The Weed Supervisor can play a key role in settling these disputes by making both sides more aware of the many factors involved in weed management.

Economic aspects of leafy spurge control

It is estimated that private landowners in Montana are spending more than 2 1/2 million dollars per year in an attempt to control leafy spurge.

A number of ranchers in the Judith Basin have weed control expenses that amount to more than their land payment each year.

As one local banker states, “some of these ranchers are paying for their places two or three times with the weed control expenses that they must incur to keep their land productive.’’

The Agricultural Stabilization and Conservation Service started participating in a noxious weed control program with landowners in 1975. The following figures show what was spent in Montana for cost-share payments on noxious weeds.

Year	Acreage	Cost
1975	39,152	$235,487.00
1976	39,648	267,112.00
1977	53,288	452,911.00
1978	58,990	488,901.00

These figures include payments for controlling all noxious weeds in Montana, not just leafy spurge, but are an indication of the growth of the problem.

The A.S.C.S. program was mainly an educational program to create an awareness of the noxious weed problem among landowners. A quick look at the figures reveals that it was indeed an effective program in that respect. Many people were made aware of noxious weeds and the increased participation in the program during its final two years is quite evident.

In terms of production losses associated with leafy spurge on rangeland, L. 0. Baker, Assistant Professor of Agronomy at Montana State University, Bozeman, reports that tests he conducted in the Gallatin Valley show that leafy spurge infestations resulted in rangeland carrying capacity losses of up to 75% (50% yield reduction in rangeland production and 25% loss in utilization due to existing grasses being intermixed with leafy spurge which is not palatable to cattle).

Assuming a carrying capacity of 4 acres per A.U.M., this would reduce the carrying capacity on the 546,355 acres of rangeland reported infested with leafy spurge from 111,588 A.U.M.'s down to 27,897 A.U.M.'s.

If you graze your cattle from May 1 to November 30 as you can some years, that would mean a reduction in cow numbers by 11,956 head (from 15,941 down to 3,985).

Carrying this on, let's assume a 90 percent calf crop and 500-pound calves at 95 cents per pound, the loss in dollars to the beef cattle industry in the state of Montana would amount to $5,110,715.00 annually.

What we are doing with the problem

We all seem to be in agreement that leafy spurge is a problem, but what can you or I do about it?

Last fall, we held a Leafy Spurge meeting in Stanford, Montana on December 1. Representatives of the Montana Extension Service, Agricultural Experiment Station, Forest Service, Bureau of Land Management and the Burlington Northern Railroad met with state legislators and landowners to discuss the leafy spurge situation.

One of the major recommendations from the meeting was the need for a biological control program to supplement existing methods of controlling leafy spurge.

The result was House Bill 410, introduced into the 1979 Legislature by Representative Bob Thoft of Stevensville and supported by a number of other key legislators.

The bill called for an appropriation of $138,500 to fund a biological control program on leafy spurge for the biennium. The bill passed the House with only two dissenting votes and went on to clear the Senate.

This funding will provide $63,500 to construct a greenhouse for propagating and screening insects for leafy spurge control with the balance of the money going to run the program for two years.

The farm organizations within the State gave their support to this bill also as did a great many private landowners and concerned citizens.

Dr. Gary A. Strobel, plant pathologist at Montana State University is currently starting a research project to examine phytotoxins produced by pathogens that attack weeds (bacteria and fungi). These compounds have the likelihood of being specific, biodegradable and very effective in weed control.

Dr. Strobel is an outstanding scientist and has conducted some of the top plant pathology research in the United States.

We need to get behind him and help in any way possible to see that his work in weed control is carried out as this could very well prove to be one of the bright spots of the future for noxious weed control.

According to researchers, funding is badly needed for selecting and screening insects in Europe to be exported to this country for biological control of leafy spurge.

The insects, once collected, must undergo rigorous testing and evaluation both in the foreign country where found and also once they arrive in the United States to make sure that they do not carry harmful pathogens and also to make sure that they are host specific to leafy spurge.

The process, which is a very necessary part of a successful biological control program, requires a great deal of time and money. Any support that you can give to this program will be of value toward increasing the size and scope of the biological control program that is in effect today.

Controlling leafy spurge is not an easy task. It will take the cooperation of all organizations and individuals related directly and indirectly with the problem to bring it under control.

It will mean a real commitment by the people involved in terms of dollars, both for research and chemical control, and in time; time to learn more about the problem yourself and time to teach your neighbor more about what you have learned.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 25-34.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

The biological control of leafy spurge

DR. PETER HARRIS

Research Scientist, Agriculture Canada, Research Station, Regina, Saskatchewan

Abstract:

Biological control of weeds is the use of a living organism to reduce the density of the target weed to below the economic threshold.

It can involve the management of existing organisms or the annual application of an insect or pathogen as a biological herbicide. The control of leafy spurge with sheep is a form of biological control. However, the most promising long term solution for leafy spurge involves the introduction and establishment of an organism in North America from another part of the world. This type of biological control, which is sometimes called biological control by inoculation, is the subject of this paper. It does not involve eradication of leafy spurge since a residual population of the weed is required to maintain the biological control agent, but if biological control is successful this residual population is below the level at which the weed is a problem.

This paper considers the strengths and weaknesses of leafy spurge as a candidate for biological control. It discusses the results of biological control against other weeds and the ways in which control agents can be made more effective. Finally the progress and plans for the biocontrol of leafy spurge are discussed.

Leafy spurge as a target for biocontrol

1. Availability of monophagous agents

Biological control depends on the existence of monophagous insects in another part of the world that are not present in North America. Leafy spurge is a weed of European origin that in North America is attacked by a few polyphagous insects and a rust, *Uromyces striatus*, that alternates on clovers. In contrast there are at least 96 insect species that attack the genus *Euphorbia* in Europe of which 70 appear to be restricted to it. Not all of these will feed on leafy spurge, but there is certainly a good choice of species that will accept it. Furthermore, many of these are from a climatic area similar to the Canadian and United States prairies. Leafy spurge appears to be an excellent target for biocontrol in this respect.

2. Relation of leafy spurge to economic or desirable plants

The closer the taxonomic relationship of leafy spurge to a desirable plant the fewer the organisms that will distinguish between them. A few *Euphorbia* species are grown as ornamentals in North America and if necessary, it probably would be acceptable to protect them with insecticide. I am sure that the cost of this would be a fraction of the saving achieved by the control of leafy spurge. Native wild spurges are of greater concern, as they cannot be protected. Also, in the past few years, there have been press reports that *E. lathyris* and other species of spurge can be grown to produce petroleum substitutes at less than $20 a barrel. This is roughly the present cost of imported crude. The existence of an industry based on *Euphorbia* spp. would reduce the choice of agents that can be used for biological control.

Fortunately, many species of spurge insects are extremely host specific so it should be possible to find insects that will not attack close relatives of leafy spurge. Thus, leafy spurge is an acceptable candidate in this respect, although there are some difficulties.

3. Prospective cost/benefit of biological control of leafy spurge

The only justification for the control of an agricultural weed is to increase economic returns and control should not be attempted if the cost is more than the long-term benefits. Similarly, biological control should not be used unless the prospective cost/benefit ratio is more favorable than for the alternatives. All too often, it is selected as a last resort after chemical control has failed, which does not necessarily make it a good prospect for biological control.

The probable cost of biological control of leafy spurge can be determined from its average cost for other weeds. It is difficult to do this in monetary terms because of inflation and the several currencies involved, but the scientific manpower required to complete a biological control procedure is rather constant. Thus, I have determined the costs in scientist-years for the various procedures in a biological control program. I have assumed that to achieve control of leafy spurge, five agents will have to be introduced, of which four will become established. The international average per weed seems to be approaching this figure. The probable costs on this basis are around 20 scientist-years (Table 1) and within two years the cost of a scientist-year will be approximately $100,000. Thus, the expected cost for the biological control of leafy spurge is around $2 million. This cost remains constant whether the program is done solely by Canada or jointly by Canada and the U.S.A. A more detailed discussion of cost is given by Harris (1979).

The easiest benefits to determine are the savings from not having to use chemical control. Saskatchewan in 1977 spent approximately $92,400 for the chemical control of leafy spurge and I guess that the total annual expenditure for chemical control of leafy spurge in Canada and the U.S.A. is in excess of $10.5 million.

The actual benefits from removing leafy spurge are harder to determine than the savings in chemical control. Biological control will reduce the abundance of leafy spurge, but this does not mean that present infestations will revert to grass or clover. The probability is that other weeds will replace it as happened with the biological control of St. John's wort with two beetles in an Ontario meadow (Table 2). The value of the St. John's wort control in this example depends on the objective; biological control was more effective in removing a toxic weed than increasing forage yield. Returning to leafy spurge, I think that the main objective in most sites is the control of leafy spurge, regardless of the species that replace it.

In order to economically justify any leafy spurge control program, whether it is chemical or biological, some of the data that is needed is as follows:

a. What is the cost of controlling leafy spurge in arable land in the form of extra cultivations or summer fallow?

b. Will the presence of leafy spurge in arable land prevent the use of zero till and continuous cropping and how much loss is this going to mean to the farmer?

c. What are the costs of controlling leafy spurge in grasslands and what are the losses associated with not controlling it?

d. How much area will leafy spurge affect if it is not controlled?

e. How fast is leafy spurge spreading with the present level of control?

f. Can chemical control of leafy spurge be improved until it is cheaper than biological control?

It is my feeling that when the economic data has been collected it would justify a major chemical control program to contain leafy spurge for the next 20 or more years until biological control can be fully effective. If economic data is not collected, it is likely that biological control will continue on a low priority basis as it has since 1962. The total sum required does not seem much until it has to be obtained in competition with many other deserving needs from the public purse. Also, it must be available in relatively uniform installments for a minimum of ten to fifteen years.

Results of biological control against various weeds

It does not automatically follow that the establishment of a biocontrol agent will reduce the density of the weed. The difficulty is that monophagous insects normally do not have much impact on the population dynamics of their host plant. This occurs because hosts with same resistance survive to contribute most seed to the next generation (Pimentel 1961). Thus, the result of introducing a monophagous control agent is homeostasis between it and the weed in which both survive at high densities. Biological control is only successful if this homeostasis is broken.

An example of homeostasis is the cinnabar moth (*Tyria jacobaeae*) which was introduced for the biological control of tansy ragwort (*Senecio* j*acobaea*) in British Columbia. The moth increased to defoliate the weed, but the weed regenerated later in the summer to build-up its root reserves and overwinter as a normal herbaceous perennial (Harris *et al*., 1978a). The average density of the weed has declined by roughly a third in the 14 years since introduction of the moth (Figure 1). Thus, the cinnabar moth is a well-adapted insect that on this site has not greatly reduced the abundance of its host plant, and as a biocontrol agent it is a failure.

The same moth on the same weed in Nova Scotia has had a different effect (Figure 2). In the shorter growing season of the east coast, the first frosts often occur while the defoliated plants are still regenerating rapidly and hence are frost tender (Harris *et al*., 1978b). The result is that homeostasis has been broken by the winter kill of the moth defoliated plants. Biological control is a success as both the weed and the moth have declined to continuous low density.

The investigator has four procedures by which he can try to break homeostasis and frequently more than one is necessary to achieve control. With the objective of producing more agents per plant, the mortality of the agent can be decreased or its natality can be increased. Conversely, the mortality of the plant can be increased or its natality can be decreased.

Decreasing agent mortality

Routinely, the mortality of the agent is decreased by introducing it free of parasites. As a result, the density of the agent may be increased markedly. For example, in Europe, Zwölfer (1971) found that an average of 1.6 *Rhinocyllus conicus* developed per nodding thistle head (*Carduus nutans*), whereas in Saskatchewan where it was introduced without parasites and competitors, it achieved a density of 4.5 *Rh*. *conicus* per head in 1975.

A more striking example is the knapweed seed-head fly *Urophora affinis*. In Europe, Zwölfer (in litt 1979) found an average density of 0.3 (range 0.007-0.9) larvae per spotted knapweed head (*Centaurea maculosa*). At Chase, British Columbia, the population has stabilized without parasites at 3.3-5.0 larvae/head.

Increasing plant mortality

The cinnabar moth was effective in Nova Scotia because an increase in plant mortality supplemented the effects of the moth. Plant mortality can also be increased by establishing additional agents on the weed. For example, the establishment of the tingid *Teleonemia scrupulosa* in Hawaii for the biological control of *Lantana camara* caused considerable summer defoliation, but the shrub recovered in the remainder of the year. However, with the introduction of three species of Lepidoptera that were most active in the winter, excellent control was achieved in the drier areas (Andres and Goeden 1969).

In total, 16 agents have been established on *L. camara* in Hawaii to cover the growing season and the wide ecological range of the weed (Harris 1979).

In British Columbia, we have introduced the beetle, *Longitarus jacobaeae*, that feeds on the roots of tansy ragwort in the fall and spring as a means of supplementing the summer defoliation of the cinnabar moth. Australia has established an average of 3.7 insects against 20 weeds targeted for biological control (Cullen, in litt 1979) and insects are still being introduced against some of them. Thus, it is reasonable to suppose that we will have to establish four agents on leafy spurge.

Another method of increasing the mortality of a weed is by encouraging competition from grass and other vegetation. For example, the weevil *Rh. conicus* reduced the density of *C. nutans* in a Saskatchewan pasture by about 90%, but in a nearby gravel pit, with little competition from other vegetation, thistle density remained high except when it was winter killed as a result of poor snow cover. In Virginia, where there is a good distribution of summer rain for grass growth, thistle density declined by 95% following the introduction of the weevil (Kok and Surles 1975). Thus, pasture management procedures that encourage a vigorous sward will aid in biological control of weeds.

Increasing natality of the biological control agent

An attempt to increase agent natality is suggested for species that are density independent. It will not work with species in which competition for egg sites, competition between newly hatched larvae or other density dependent mechanisms control the population well below the starvation level. The knapweed seedhead gall flies, *U. affinis* and *U. quadrifasciata* (Harris 1979) seem to be insects of this type as the average number of galls/head in different species of knapweed is closely related to head diameter.

Most crop pests are density independent species that increase to the limit of their food supply when conditions are favorable. Under natural conditions, their fecundity is limited by the availability of protein or essential amino acids. For example, Smith and Northcott (1951) showed that a common grasshopper (*Melanoplus mexicanus*) fed on wheat plants with a nitrogen content of 6.16% produced 66% more eggs than on plants with a content of 4.29% nitrogen.

Similarly, strawberry varieties with a nitrogen content of 1.56% were resistant to the spider mite *Tetranychus urticae* as the mite had a low fecundity, whereas strawberries with a content of 2.03% were susceptible (Dabrowski 1976). Also, pea varieties with an amino acid content of 2% were resistant to the aphid *Acyrthosiphum pisum*, while those with a 3.75% amino acid content were susceptible (Auclair 1976).

The nitrogen content of plants can be increased with nitrogen fertilizer; this is one of the reasons for outbreaks of crop pests. The same practices can be used on biocontrol agents. For example, in one region of Australia. *Cactoblastis cactorum* survived on prickly pear, but it did not give control. Nitrogen was applied to the weed and the resulting outbreak of the moth controlled the prickly pear (Dodd 1940). Presumably, the nitrogen was then available for grass growth so that it served two purposes.

I think that the control of St. John's wort (*H. perforatum*) by *C. quadrigemina* may partly depend on the nitrogen content of the plant. In Europe, the weed is found chiefly on nitrogen poor gravels and rocky soils, but in British Columbia it also formed dense stands on fertile soils such as the bench lands above Okanagan Lake at Westbank. The establishment of the beetle reduced the weed at Westbank to a few scattered plants and has been maintained at this density for 15 years. However, on the less fertile alluvial gravels near Cranbrook, B. C., the weed has continued to spread in spite of the presence of the beetle. I think that it would be worth trying an application of nitrogen at the Cranbrook site as both the eggs and larvae can be crowded without apparent ill effects.

Decreasing natality of the weed

Any treatment of the weed that can be done to decrease seed production without harm to the control agent will assist in breaking homeostasis. For example, in Saskatchewan, late flowers produced by *C. nutans* are not attacked by *Rh. conicus*. Miller (1978) found that stands in Montana mowed in early August decreased average seed production from 26 to six seeds/head with only a slight decrease in weevil survival.

This approach is less attractive than some of the others suggested, because it requires an annual treatment to remain effective. Nevertheless, it may be useful in certain instances.

Progress in the biological control of leafy spurge

The Commonwealth Institute of Biological Control (CIBC), on behalf of Agriculture Canada, has since 1962 surveyed leafy spurge in Europe for insects. For the last two years, this survey has received a high priority and the United States Department of Agriculture has extended the survey region further to the south and east. A new species of clear-winged moth, *Chamaesphecia tenthrediniformis* from *E. esula* was described as a result of the survey and a beetle, *Leptura bisignata*, whose host was previously unknown was reared from spurge (Schroeder, in litt 1978). However, the main achievement of the survey has been to indicate the biocontrol potential of various insect species from their abundance, distribution and damage to the host. There are 25 insect species that I think warrant further investigation.

Biological control agents cannot be released in North America until host specificity tests have been completed and approved by authorities in Ottawa and Washington. As a result of Agriculture Canada studies, the spurge Hawkmoth, *Hyles euphorbiae* was released in 1965. In this and subsequent years, over 56,000 larvae were released on cypress and leafy spurge in Ontario, Manitoba, Saskatchewan, Alberta and British Columbia with additional numbers released in the United States. Most of the colonies declined rapidly with up to 88% of the larvae disappearing within four days of their release, partly from ant and carabid predation (Harris and Alex 1971). At Braeside, Ontario, where only 65% of the larvae disappeared within four days, establishment was eventually obtained (Table 3). The larvae released in 1968 and 1969 were the progeny of the first field survivors that had been increased in the laboratory over winter. Thus, they had been subject to selection in the field for at least one year.

The moth has spread over the 30 square miles of the infestation, but the population seems to have stabilized at around one to two larvae/m^2. On the basis of the amount eaten by a larva (New 1971), approximately 14 larvae/m^2 are required for defoliation of the spurge. Thus, in terms of control, the moth has been of little value. The only other colony established, as far as I am aware of, is on poor sandy soil at Stirling, Ontario, where very scattered larvae have been recovered. I think it would be possible that both the Braeside and Stirling colonies might respond to nitrogen fertilizer as the moth does not have a density limiting behavior at either the egg or the larval stage. ,

The second insect authorized for release was *Chamaesphecia tenthrediniformis* which had been screened by the CIBC for Agriculture Canada (Schroeder 1969). From 1970, over 7,000 eggs or newly hatched larvae were transferred to spurge in the field or in pots and 98 moths were released directly into the field. Most of the transferred larvae died without feeding, although a few placed into artificial tunnels in the spurge survived for a week or two. In Europe, there had been no problems in transferring the larvae to other *E. esula* plants, but in Austria it was noticed that, although almost all typical *E. esula* plants had eggs laid on them by *Ch. tenthrediniformis*, *E. virgata* (a spurge similar to *E. esula*) was never attacked (Schroeder 1978, in litt). Doubts about the identity of our leafy spurge deepened when an aphid, *Acrythosiphum neerlandicum* which is only known from *E. esula* in Europe, became alate and died within three weeks when transferred to Saskatchewan leafy spurge.

A screening report on the root boring beetle, *Oberea erythrocephala* was submitted for release approval in 1979. This has been approved by Canada, but the United States has requested that tests be done on *Croton* and other plants important for wildlife in the southwest. As far as I am concerned, *O. erythrocephala* is an exciting prospect; it will attack our spurge and high levels of attack in Europe resulted in a sharp decline in the number of flowering stems in the following year (Schroeder 1979).

Plans for the biocontrol of leafy spurge

The overall plan is to test as many European insects as possible on North American leafy spurge and if it is accepted, to conduct more detailed studies in order to obtain approval for release of the insect in North America. The following are the main studies planned or underway; although the plans are subject to change if other species are more available:

Aphthona spp.

There are 25 or more species of *Aphthona* associated with the genus *Euphorbia*. The larvae feed on the roots in the fall and spring while the adult beetle does minor damage to the leaves and shoots in the summer. Screening studies with several species are being done by the CIBC with funding from Alberta. In addition, Mr. E. Maw is doing a masters study at the University of Alberta on the econogy and larval morphology of the genus. In three or four years time there should be one or more species available for release.

Chamaesphecia sp.

Two specimens of an unidentified *Chamaesphecia sp* were reared by Dr. D. Schroeder from *E. virgata*. As *Ch. tenthrediniformis* is the main insect controlling *E. esula* in Austria, we would like to test species from *E. virgata* on our leafy spurge.

Dasyneura capsulae and *Bayeria capitigena*

These gall midges are to be investigated by the United States Department of Agriculture.

D. loawi and *D. subpatula*

It is planned to import collections of these gall midges for studies in the Agriculture Canada quarantine facilities at Regina, Saskatchewan.

Eriophyes euphorbiae

If a source of this gall mite can be found, a colony will be imported to Regina for host specificity test.

Oberea erythrocephala

The final host specificity tests requested will be completed and hopefully the insect will be released in 1980.

Eurytoma euphorbiae

This seed chalcid, widely distributed in the USSR, is reportedly restricted to *E virgata*. I hope to import some to determine if it will accept our leafy spurge.

Polychrosis euphorbiae

This stem-boring moth will be screened by the CIBC under funding from Saskatchewan.

Simyra nervosa

I understand that the United States Department of Agriculture is hoping to investigate this noctuid moth.

Taxonomy of North American leafy spurge

Moore (1958) placed all the collections of Canadian leafy spurge in the species *Euphorbia esula*. However, according to the Flora USSR, Saskatchewan leafy spurge keys to *E. virgata* because the lower 2/3 of the styles are united rather than merely joined as the base as in *E. esula* Unfortunately, in spite of its extreme host specificity, the moth *Ch. tenthrediniformis* in Austria attacks plants with both united and separated styles (E. Maw Per. com.). The differences observed by insects between host and non-host plants in the leafy spurge complex are likely to be chemical rather than morphological, but until these differences have been identified, the efficiency of search for biocontrol agents of North American spurge will be low. I hope that it will be possible to investigate biosystematics of leafy spurge by first using insect species to separate plants into susceptible and non-susceptible categories and then finding chemical or morphological characters that distinguish them.

Conclusions

1. Leafy spurge is a good candidate for biological control.
2. Large expenditures for the control of leafy spurge or for research on it cannot be justified without better data on the present and future losses from the weed. I suspect that in part it is a matter of consolidating information already available.
3. Biological control of leafy spurge would be easier if we could recognize and know where to find the European counterpart of North American leafy spurge.
4. A major acceleration in the biological control of leafy spurge would require the addition of one two-scientist years for a minimum of 5 years.
5. At present there are two agencies in North America directly involved in the biological control of leafy spurge with several other agencies assisting with funding. If more agencies became directly involved, I suggest that a coordinating committee should be formed to avoid needless duplication.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 35-52.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

Cropping cultivation, and herbicides to eliminate leafy spurge and prevent reinfestation

LYLE A. DERSCHEID

Extension Agronomist and Professor of Plant Science, South Dakota Cooperative Extension Service. Formerly leader of weed research project with South Dakota Agricultural Experiment Station 1946-1964.

Since the Proceedings of this Symposium are to be used as a leafy spurge control reference manual, the writer has included most of the information from two of his papers published in *Weeds* in 1960 and 1963, including a "Review of Literature" and "Bibliography" that may be useful to some of the readers.

Though the control methods that include intensive cultivation and annual crops may not be useable in grassland or wooded areas, the treatments involving perennial grasses may be useful. The methods discussed here, though developed two decades ago, are believed to be the best methods available for use in eliminating leafy spurge on cultivated land.

The following exerpts were taken from the paper listed as Number 15 under "Literature Cited".

Leafy spurge is a perennial weed that is found in almost every state north of the fortieth parallel and in the southern portions of most Canadian provinces. Heaviest infestations are found in Minnesota, the Dakotas and the Prairie Provinces.

Hanson and. Rudd (10) conducted extensive life history studies in North Dakota. They adopted the name *Euphorbia virgata* Waldst. & Kit.; however, Stevens (12), also of North Dakota, used the name *Euphorbia esula* L. The two names apparently were used for the same species. Hanson and Rudd (10) described it as a long-lived perennial herb, somewhat woody at the base, containing milk sap. It grows to a height of 14 to 40 inches and propagates by means of seeds and roots. Near Fargo, average plant height was 1/2 inch April 5, 1 1/5 inches April 19, 3 1/2 inches April 23, and 12 1/2 inches April 30. Flowers began to appear by the end of May. This rapid early growth gives the weed a great advantage over most crop plants.

"The most formidable part of the plant is the root...It is well developed. The large tap root begins to branch into a number of large, woody, brown-colored branches near the surface. The fine roots are numerous, especially near the surface and when suitable conditions occur in deeper soil. The maximum depth at which roots were found was at the water table at 8 feet. The maximum lateral spread was 3 1/2 feet'' (10). This description is very similar to the description of the root system of field bindweed (*Convolvulus arvensis* L.) given by Frazier (9). The main differences are that the leafy spurge root is more woody and less extensive in a clay soil than the root of a non-competing bindweed plant growing in a sandy loam soil. Pieces of leafy spurge roots as small as one-half inch long and one-eighth inch in diameter produced new shoots which grew rapidly (10).

The fruit is a 3-chambered capsule, explosively dehiscent, usually along the line of union of the carpels. Normally each carpel contains one seed. Nearly 50 percent of the fruits produce one mature seed, about 35 percent produce two, and 15 to 20 percent produce three. In the vacinity of Fargo, the fruits begin to ripen about July 10 and continue until September. Upon maturity the seeds are forcibly discharged up to a distance of at least 13 feet. In one test, they were uniformly distributed in an area extending from 1 to 13 feet from the parent plant (10).

Thousands of acres of South Dakota farmland are infested with leafy spurge. Since it is not economically possible to put the land out of production while the leafy spurge is being eliminated, the objectives of the study reported in this paper were to determine methods of eliminating the weed in large areas while crops adapted to South Dakota were being produced and to determine methods of eliminating small infestations with chemicals.

Very few data could be found in the literature to serve as a guide when planning the study. However, life history studies (9, 10), root reserve studies (1, 3, 4, 8), and methods of control studies[1] (2, 3, 11, 13) indicated that leafy spurge and field bindweed were similar in growth habits, and that some of the methods for eliminating field bindweed were effective for the control of leafy spurge.

When bindweed roots were cut 4 inches below the soil surface every 14 days, root reserves were reduced (8). A duckfoot cultivator proved to be an effective implement for cutting the shoots in the field (11, 13), and it was desirable to start operations early in the spring to take advantage of the decline in root reserves during the winter (4). The 14-day interval between cultivations sometimes could be lengthened to 3 weeks, especially during the late summer when plants became dormant (13). In other work, the best interval was 2 weeks for bindweed, 3 weeks for Russian knapweed *Centaurea repens* L., and 4 weeks for hoary cress (*Cardaria draba* (1.) Desv.) and dogbane (*Apocynum cannabinum* L.) (14). Complete elimination of these weeds was obtained in 1 to 2.5 years. To secure similar results with leafy spurge, it was necessary to cultivate semiweekly for 2 years when a spring-tooth harrow was used (2).

Early spring cultivation, followed by a close-seeded crop of forage sorghum, soybeans, or sudangrass harvested for forage, followed by fall cultivation, reduced bindweed stands and resulted in complete elimination when continued for 3 years (3, 11, 13). Simi-

[1] Stahler, L. M., and Derscheid, Lyle A. Unpublished data from South Dakota Bindweed Research Farm, 1946-1950. These data support most of the statements made in this section on control of bindweed.

lar results were obtained with leafy spurge (2). Buckwheat was an equally effective crop on quackgrass.

Alfalfa or alfalfa-perennial grass mixtures were sufficiently competitive to reduce stands of bindweed that had been weakened by a short season of intensive cultivation (3, 11). Perennial grasses prevented bindweed from spreading (13), but were less effective for reducing stands than alfalfa or alfalfa-grass mixtures (11) However, bindweed stands were reduced by spraying bromegrass with 2,4-D. Alfalfa was less effective for controlling leafy spurge (2).

Two or three crops of winter wheat or rye alternated with intensive cultivation between crops gave elimination of bindweed (3, 11, 13), and spring sown grains were equally effective. However, spring sown grains or corn could not compete effectively with leafy spurge (2). Spraying spring sown grains with 2,4-D could be used to replace cultivation between crops for the elimination of bindweed, but elimination was obtained in less time when spraying and cultivating were both utilized.

Numerous experiments conducted by the authors indicated that 2,4-D was equal to or superior to 2,4,5-T, MCPA, and several related chemicals for control of leafy spurge. Results indicated that the ester forms of 2,4-D were more readily absorbed than the amine forms. Leafy spurge reacted to less than one-fourth pound acid equivalent per acre. However, the stand was not materially reduced by 2 or 3 treatments in 1 year with much higher rates. Although the weed was easily affected by the chemical, it was quite resistant. It appeared that the weed could be weakened with 2,4-D so that a crop could compete more effectively with it or that cultivation could kill it more readily.

These results indicated that the objectives of this study could be attained with the proper combination of crops, cultivation, and chemicals. If the area were cultivated when not occupied by a crop and if the weed were selectively sprayed in a crop tolerant to the chemical, it appeared that several combinations might eliminate the weed in a few years.

Experimental procedure and results

Screening trials in which rates, dates, formulations, and chemicals were compared had been conducted during 1948-50. It became apparent that the chemicals available were not practical for elimination of large infestations of leafy spurge. Consequently 30 acres of land heavily infested with leafy spurge were leased during 1950 to study methods of eliminating this weed. The land was a part of the Pir Nilsson estate located 18 miles northeast of Clear Lake in Deuel County, South Dakota, where annual rainfall is normally about 22 inches. The soil is a Forman loam.

Annual crops, cultivation, and 2,4-D

A 3-year experiment involving the use of annual crops (winter rye, oats, sudangrass, and buckwheat), intensive cultivation, and 2,4-D was initiated during the fall of 1950. Weed counts were made on 4 one-square-yard areas of each plot during the middle of May each year. The final counts were made in May, 1954. Identical 3-year experiments were initiated during the falls of 1951 and 1952, and they were completed during May, 1955 and 1956. Each experiment included the same 33 treatment combinations. Each treatment was repeated once in a randomized block design.

Perennial crops, cultivation, and 2,4-D

Three experiments involving the use of perennial forage crops, cultivation, and 2,4-D were conducted. They were initiated in August, 1950, 1951, and 1952, and were completed during May, 1954, 1955, and 1956. Each experiment included the same 44 treatments. Each treatment was repeated once in a randomized block design. Weed counts were made on 4 square-yard areas of each plot in mid May each year.

Discussion

Leafy spurge apparently is more difficult to eliminate than field bindweed. Although intensive cultivation appears to be equally effective on both species, the competitive crops and 2,4-D appear to be less effective on spurge.

In this study, intensive cultivation eliminated over 90 percent of the spurge in 1 year and 100 percent in less than 2 years, regardless of whether the operations were performed at 2- or 3-week intervals. Similar results have been obtained by cultivating spurge with a duckfoot cultivator every 2 to 3 weeks (6) or with a spring-tooth harrow twice each week (2). Spurge appears to be similar to bindweed as the latter was completely eliminated in 2 years or less 3 when duckfoot cultivated at 3-week intervals for the entire season (11, 13).

The "fallow-rye" method, which has been successfully used for the elimination of bindweed (3, 11, 13), was less effective for killing spurge. The stand reduction was 10, 22, and 52 percent at the end of the first, second, and third years, respectively.

Close-drilled crops of sudangrass and buckwheat appeared to be more strongly competitive than other crops used in this study. When three cultivations were performed before seeding and the stubble was plowed after harvest, these crops appeared to have the ability to reduce leafy spurge stands about 50 percent in 1 year and 80 percent in 2 years. Complete elimination of spurge in 2 years has been accomplished when a crop of close-drilled forage sorghum or soybeans was handled in a similar manner (2). However, the results in this study are similar to those obtained with bindweed[2] (3, 11, 13) when forage sorghum or soybeans was used as the competitive crop.

Previous work (2) indicates that the seeding of a leafy spurge infested area to a spring-seeded grain is a useless procedure. Similar results were obtained in this study. Spurge starts so early in the spring that it gets ahead of spring-seeded crops. However, an application of 1/2 lb/A of 2,4-D ester checks weed growth, making it possible for the grain to get ahead and hold the weeds in check. The results indicate that a reduced stand of leafy spurge can be held in check, but not further reduced during a year that a small grain crop is raised if 2,4-D application is made. This leads to the possibility of using

[2] Stahler, L. M., and Derscheid, Lyle A. Loc. cit.2

some system that will reduce the stand on alternate years with small grain that is sprayed. Alternate years of intensive cultivation and small grain sprayed with 2,4-D is an effective method (6).

Although alfalfa was a good competitive crop for controlling bindweed (3, 11), it did not compete strongly with spurge in this study or in other experiments (2). Leafy spurge emerges at or before the time that alfalfa commences spring growth, and the spurge produces a rank growth which stays ahead of the alfalfa. Bindweed, on the other hand, emerges after alfalfa develops, and its prostrate form of growth allows the alfalfa to overshadow it.

Bromegrass was effective in reducing leafy spurge stands when aided by cultivation or application of 2,4-D. A short season of intensive cultivation prior to a fall-seeded crop eliminated 95 percent of the spurge. Bromegrass was capable of holding the weed in check, without the aid of 2,4-D. However, the stand was not further reduced even when 2,4-D was used.

When the cultivation was omitted, bromegrass that was sprayed with 2,4-D slowly reduced the stand of leafy spurge. The date of treatment appeared to be unimportant although fall treatments were least effective the first year. Two treatments a year did not appear to be superior to 1 treatment.

Conclusions

1. Leafy spurge stands can be materially reduced by use of the proper combination of competitive crop, cultivation, and 2,4-D.

2. Leafy spurge reacts to small amounts of 2,4-D but is not killed by much larger amounts. Ester forms cause much greater reaction than amine forms.

3. Leafy spurge can be eliminated with less than 2 years of intensive cultivation. Operations need not be performed oftener than every 3 weeks if a duckfoot cultivator is operated at a depth of 4 inches.

4. Spring-seeded small grains do not compete favorably with leafy spurge. However, grain sprayed with 2,4-D prevents spurge stands from becoming denser.

5. Sudangrass and buckwheat, where adapted, materially reduce the stand of leafy spurge when the seeding is preceded by three cultivations and harvest is followed by plowing.

6. Alfalfa does not compete favorably with spurge unless a heavier than normal stand of alfalfa is obtained.

7. Bromegrass sprayed with 2,4-D slowly reduces the stand of leafy spurge. It is more effective when fall seeding is preceded by a short season of intensive cultivation.

8. Several soil sterilants can be used to eliminate small patches of leafy spurge.

9. Amitrol and 2.3,6-TBA show great promise for use in eliminating large infestations of leafy spurge.

The following statements are taken from the paper listed as Number 16 in the "Literature Cited" section.

Although the crops used in 1950-1956 are adapted to South Dakota, they were not used in profitable crop rotations. Consequently, a second series of studies was initiated to determine methods of eliminating large areas of leafy spurge while crop rotations adapted to South Dakota were being followed and to learn how to prevent reinfestation. During the course of this study rainfall was about 28 inches in 1956, 27 inches in 1957, 19 inches in 1958, 20 inches in 1959 and 25 inches in 1960. During April to August inc. the rainfall was 22 inches in 1956, 15.5 inches in 1957, 12 inches in 1958, 12 inches in 1959 and 20 inches in 1960.

Experimental procedure and results

The 30-acre Research Farm used for the previous studies was also used for the experiments reported in this paper. Three types of experiments were conducted: (1) 4-year trials in which information gained in the previous studies was used to develop good cropping sequences for eliminating leafy spurge, (2) 2- or 3-year trials in which non-selective herbicides were applied before planting corn and after harvesting small grain to develop methods of eliminating the weed, and (3) 4-year experiments designed to learn how common crop rotations should be managed to prevent reinfestation of land on which the weed has been eliminated.

Crops, cultivation and 2,4-D for elimination

One 4-year experiment was initiated in 1956 in which 32 treatments were applied in triplicate on plots 1 rod X 5 rods in size. The second 4-year experiment was initiated during 1957. The same treatments were applied in quadruplicate. The number of leafy spurge shoots were counted on four permanent 1-square-yard areas of each plot during mid-May before initiating the experiment. Counts were made on the same areas in mid-May of each succeeding year to determine the effect of each year's treatment. The first experiment was finished in May 1960 and the second 1 year later.

Rotations used were: (1) cultivation-alfalfa-alfalfa-corn, (2) cultivation-alfalfa-wheat-corn, (3) cultivation-bromegrass-bromegrass-corn, (4) cultivation-bromegrass-wheat-corn, (5) oats-bromegrass-bromegrass-corn, (6) oats-bromegrass-wheat-corn, (7) oats-oats-sweet clover-corn, (8) oats-oats-sweet clover and fallow-corn, (9) sudangrass-oats-sweet clover and fallow-corn, (10) sudangrass-oats-wheat-corn, and (11) sudangrass-rye-wheat-corn. They were modified with the addition of 2,4-D, and special cultivation to form 32 treatments in each experiment.

All cultivation and fallow operations were performed with a 7-foot duckfoot cultivator equipped with nine 12-inch sweeps operated at a depth of about 4 inches. The butoxyethanol ester of 2,4-D was applied in a volume of 12 gal/A for all 2,4-D applications. The treatments and data are given in Table 1.

Editor's Note: Tables referred to are not included but can be found in the original references. First year. Corn had been grown on the area during the previous year to allow the leafy spurge reinfestation to regain vigor after the previous studies had been terminated.

Plots receiving treatments 1 to 15 were plowed during mid May and cultivated at 2-week intervals (6 cultivations) between early June and mid-August. Ranger alfalfa at 8 lb/A or Homesteader bromegrass at 12 lb/A was seeded with oats as a companion crop during mid-August in these treatments. The stand of leafy spurge was reduced 82 percent for the 105 plots in the two experiments.

Plots receiving treatments 16 to 22 were tandem disked twice and drilled to oats at 1 1/2 bu/A and Homesteader bromegrass at 12 lb/A during mid-April. All plots were sprayed with 1/3 lb/A of 2,4-D during early June, when the oats were in the 5-leaf stage, and plowed during late August. The stand of leafy spurge increased 62 percent on the 49 plots treated in this manner.

In treatments 23, 24 and 25, oats were seeded at 2 1/2 bu/A. Treatments 24 and 25 included spraying with 1/3 lb/A of 2,4-D when grain was in the 5-leaf stage. All three treatments included post-harvest plowing in late July, a cultivation in late August and two cultivations in September. Treatment 23 allowed the weed population to increase 19 percent on 7 plots, while treatments 24 and 25 reduced the stand 68 percent on 14 plots.

Plots receiving treatments 26 to 32 were plowed during mid May and cultivated three times before Piper sudangrass was seeded with a grain drill at 25 lb/A during late June. Hay was harvested during early September and all plots were plowed immediately. Treatments 26 to 29 reduced the stand 79 percent on the 28 plots. Pierre rye was seeded at 1 1/2 bu/A on treatments 30 to 32 immediately after plowing. This procedure reduced the stand 90 percent on the 21 plots.

Second year. The stand of alfalfa was very poor in treatments 1 to 5. Alfalfa was reseeded top-dressed with 100 lb/A of 0-46-0 fertilizer in mid-May, and cut for hay during mid-August. Treatments 2 to 5 included plowing early in September. This sequence had little effect on the stand of leafy spurge.

The bromegrass in treatments 6 to 15 was top-dressed with 120 lb/A of 33-0-0 fertilizer in mid-May and a hay crop was harvested during mid-June. Treatments 6 and 9 reduced the stand slightly. In treatments 7, 8 and 10 to 15, bromegrass was sprayed with 2,4-D at 1 lb/A in early June. In treatments 8 and 12 to 15, grass was sprayed with an additional 1 lb/A of 2,4-D in mid August. All (7, 8 and 10 to 15) were plowed in early September, reducing the stand an additional 12 to 13 percent, indicating that the August application of 2,4-D in treatments 8 and 10 to 15 was not effective in reducing the leafy spurge stand.

Treatments 17 to 19 included one application of 2,4-D on bromegrass, while treatments 16 and 20 to 22 included two applications. All except treatment 16 included fall plowing. The stand of leafy spurge was reduced 51 percent at the end of 2 years on the 21 plots receiving one spraying the second year, and 54 percent on the 28 plots receiving two sprayings the second year, indicating once again that the August spraying was not effective.

Treatments 23 and 26 utilized an oat crop at 1 1/2 bu/A underseeded with Madrid sweetclover at 8 lb/A and no spraying. Both allowed the stand of leafy spurge to increase. Treatment 24 included a crop of S.D. 270 corn, three cultivations and an application of 1/3 lb/A of 2,4-D between the first and second cultivations. By this method, leafy spurge stands were reduced by about 15 percent. Treatment 25 included cultivation and sudangrass as in the first year of treatments 26 to 29. It increased elimination by 20 to 25 percent.

Treatments 27 to 29 included a seeding of Garry oats at 2 1/2 bu/A and an application of 1/3 lb/A of 2,4-D during early June when the grain was in the 5-leaf stage. In addition 1 lb/A of 2,4-D was applied during mid-August in treatment 28. The stubble in treatments 27 and 28 was plowed in mid September, but it was plowed during late July in treatment 29 and cultivated three times during August and September. Each treatment increased the percentage of elimination by almost 20 percent.

Treatments 30 to 32 were the same as treatments 27 to 29 except that rye was used as the crop instead of oats. Each increased the percentage of elimination during the second year. At the end of 2 years, the results from treatments 27 to 32 were very similar.

Third year. Treatments 1, 6, 7, 8 and 16 included a crop of alfalfa or bromegrass that received the same fertilizer treatments as the previous year. Hay was harvested in mid-June and plots were plowed during September. Without a spraying the crops had little effect on the stand to improve materially on 94 or 95 percent elimination, but two applications of 1 lb/A of 2,4-D in treatment 16 improved on 51 percent elimination from the previous year by about 30 percent. Although treatment 16 allowed the stand to increase the first year, it was equal to treatments 2 and 6 at the end of the third year.

Treatments 23 and 26 included sweetclover that was plowed during late June, tandem disked in July and cultivated five times during late July, August and September. Both improved the results materially, over the first year. All other treatments included a crop of Selkirk wheat at 1 bu/A. In treatments 2 and 9, the crop was harvested and the Stubble plowed in early September. The stand of leafy spurge was not affected.

Treatments 3, 10, 13, 17, 20, 27 and 30 included an application of 1/2 lb/A of 2,4-D during early June when the crop was in the 5-leaf stage, and a fall plowing during late August. The average of 81 percent elimination for these treatments at the end of 2 years was not changed. However, the average of 92 for treatments 3, 10, 13, 27 and 30 was maintained.

Wheat in treatments 4, 11, 14, 18, 21, 28 and 31 was sprayed with 2,4-D at 1/2 lb/A in early June and 1 lb/A after harvest and plowed in September. The average for these treatments was 80 percent at the end of 2 years and 87 percent at the end of 3 years. The average for treatments 4, 11, 28 and 31 was 92 at the end of 2 years and 97 at the end of 3 years.

Treatments 5, 12, 15, 19, 22, 24, 25, 29 and 32 included 1/2 lb/A of 2,4-D in early June, plowing in late July and three cultivations in August and September. Again the average for these treatments, 80 percent elimination at the end of 2 years, was not materially changed the third year.

Fourth year. All treatments consisted of a crop of S.D. 270 corn that was cultivated three times. An application of 1/3 lb/A of 2,4-D between the first and second cultivations was included in treatments 3 to 5 and 10 to 32. Treatments 1 to 9 eliminated 88 percent in 3 years and 85 percent in 4 years. Treatments 10 to 32 eliminated 77 percent of the weed in 3 years and 77 percent in 4 years. The results indicate that corn, with or without spraying, had little effect on the stand of the weed.

Crop yields. Average yields of unsprayed oats were 32 bu/A for the first year and 54 for the second year, while yields of oats sprayed with 1/3 lb/A of 2,4-D were 37 and 60 bu/A, respectively. Average wheat yields were 16 bu/A for unsprayed plots and 14.6 for those sprayed with 1/2 lb/A of 2,4-D. Unsprayed corn produced 31 bu/A, while that sprayed with 1/3 lb/A of 2,4-D yielded 34 bu/A. Fall-seeded bromegrass in treatments 6 to 15 yielded an average of 0.31 T/A the second year, while spring-seeded bromegrass in treatments 16 to 22 produced 0.34 T/A.

Summary. Exactly half of the treatments eliminated 90 percent or more of the leafy spurge in 4 years. These included nine of the fifteen treatments that utilized a season of intensive cultivation before seeding a perennial crop the first year and six of the seven treatments that included cultivation and a crop of sudangrass the first year. The other treatment included cultivation and sudangrass the second year. Only two of the five treatments utilizing cultivation and alfalfa the first year eliminated over 90 percent of the spurge in 4 years. Third year operations were important. Alfalfa or wheat without post-harvest operations were inferior to wheat that was sprayed in the grain and either sprayed or cultivated after harvest.

Seven of the ten operations that included cultivation and bromegrass the first year eliminated over 90 percent of the leafy spurge. The use of brome the second year and either brome or wheat the third year without 2,4-D application or the use of brome for 2 years with only one application each year proved to be ineffective in treatments 6, 7 and 9. However, two 2,4-D applications a year in bromegrass for 2 years (treatment 8) increased the effectiveness. One or two applications in bromegrass the second year, a fall plowing and a wheat crop that was sprayed the third year also proved to be effective follow-up operations to the cultivation and bromegrass used the first year.

One year of cultivation and sudangrass (treatments 25 and 27 to 32) were such effective operations that spraying in small grain reduced stands still further the next year and similar operations maintained the percentage kill in subsequent years.

Crops, cultivation, 2,4-D and non-selective herbicides

In previous studies 4 to 6 lb/A of 2,3,6-trichlorobenzoic acid (2,3,6-TBA) applied before planting corn reduced leafy spurge stands 80 to 90 percent, while similar herbicidal applications in oats stubble reduced stands 75 to 85 percent. These combinations of treatments were incorporated into one 3-year experiment and three 2-year experiments. In two experiments corn was planted the first year and oats the second. The crop sequence was reversed in the other two. Treatments were applied in triplicate on plots 1 rod by 3 rods. Leafy spurge counts were made on four permanent 1-square-yard areas before initiating each experiment and during mid-May each subsequent year to determine density at the outset and the effect of each year's treatment.

In each test butoxyethanol ester of 2,4-D at 1/3 lb/A was applied to the crop. Liquid formulations of herbicides were applied in 12 gal/A of spray solution while wettable powders were applied in 20 gal/A. Dimethylamine salt of 2,3,6-TBA and 3-amino-1,2,4-

triazole (amitrole) were used in all four experiments, while the dimethylamine salt of polychlorobenzoic acids (PBA) was tested twice, 2-chloro-4,6-bis(ethylamino)-s-triazine (simazine) and the butyl ether ester of 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) were tested once. Treatments and data for 2,3,6-TBA and amitrole are given in Table 2.

Oats and corn. Experiment 1 in Table 2 is one of two experiments in which oats was grown the first year. Treatments were not identical in the two trials, but results were similar for treatments common to both tests.

During the first year the oats was sprayed with 2,4-D when in the 5-leaf stage. In mid-August herbicides were applied to the stubble. Plowing was performed 10 days later on PBA- and 2,3,6-TBA-treated plots and 15 days later on amitrole-treated plots. PBA was unsatisfactory in the first test and omitted from the second. However, 2,3,6-TBA and amitrole reduced leafy spurge stands materially.

During the second year, 2,3,6-TBA and amitrole were applied in mid-May when leafy spurge was 6 to 10 inches tall. Ten days later all plots were duckfoot cultivated. S.D. 270 corn was planted immediately. It was cultivated three times during the season, and sprayed with 2,4-D one week after the first cultivation. The stand of leafy spurge became more dense on all plots in both experiments. There was no evidence of crop injury from most treatments even though two applications were made in a period of 9 months. Slight damage to the corn was noted on plots treated with 6 lb/A of 2,3,6-TBA in August plus 4 lb/A in May. Corn was damaged severely by a similar treatment in a test on Russian knapweed.

Corn and oats. Experiment 2 in Table 2 is one of two tests in which corn was planted the first year. In one test silvex at 5, 10 or 15 lb/A, simazine at 2, 4, or 8 lb/A, PBA at 2, 4, 6 or 8 lb/A, 2,3,6-TBA and amitrole at rates shown in Table 2 were applied in mid-May. Ten days later the plots were plowed. Corn was planted, cultivated and sprayed with 2,4-D. PBA and simazine were ineffective. Silvex equalled 2,3,6-TBA and amitrole for weed control, but killed the corn. The rates of 2,3,6-TBA and amitrole were not all identical with those in Experiment 2, but results were similar for rates that were common to both trials. Both herbicides reduced the stands materially.

During the second year, oats was handled the same as described for Experiment 1. The stand of leafy spurge was not materially decreased in either trial. No crop damage was noted either year. Herbicide applications were 15 months apart and a 9-month period elapsed between the second application and the planting of the next crop.

One test was continued a third year. Third-year treatments were a repetition of first year treatments with the herbicides applied before planting corn. Both 2,3,6-TBA and amitrole held the leafy spurge in check but failed to reduce stands materially.

Crops, cultivation and herbicides to prevent reinfestation

Two 4-year experiments were initiated in 1956 and 1957 and terminated in May 1960 and 1961. Each was conducted in quadruplicate on areas where leafy spurge had been weakened by previous experiments and eliminated with intensive cultivation for one season. No leafy spurge plants were found on four 1-square-yard areas of each 1-rod X 5-rod plot when the trials were initiated. The number of established shoots was determined on the same four 1-square-year areas each May to determine the effect of each year's treatment.

Five basic rotations, (1) oats-oats-wheat-corn, (2) oats-corn-wheat-corn, (3) oats-alfalfa-wheat-corn, (4) oats-sweet clover-wheat-corn and (5) oats-sweet clover and fallow-wheat-corn were each modified four times by the use of 2,4-D or 4-(2,4-dichlorophenoxy) butyric acid [4-(2,4-DB)] 4-(2,4-DB) and special cultivation to form 20 treatments. All cultivation and fallow operations were performed with a duckfoot cultivator. The butoxyethanol ester of 2,4-D was used for most spraying, however, a triethanol amine of 2,4-D was used in the first year of several treatments. The treatments and data are presented in Table 3.

First year. Oats was seeded at 2 1/2 bu/A in treatments 1 to 8. One-fourth lb/A of 2,4-D amine, in treatments 2 to 4, and 1/3 lb/A of 2,4-D ester, in treatments 6 to 8, were applied when oats were in the 5-leaf stage. Treatments 3 and 7 included 1 lb/A of 2,4-D in grain stubble during mid-August. All included plowing early in September except 4 and 8 which included plowing during late July and two cultivations during August and September. Only two treatments allowed more than one leafy spurge plant per square yard to become established.

Treatments 9 to 20 included oats at 1 1/2 bu/A under-seeded with Ranger alfalfa or Madrid sweetclover. Three treatments in each rotation included an application of 1/4 lb/A of 2,4-D amine in the first test and 1 lb/A of 4-(2,4-DB) in the second. A poor stand of sweetclover was obtained in the first trial and only a fair stand in the second. The treatments without spraying allowed less than one leafy spurge plant per square yard to become established, while those with spraying allowed almost two plants. The legume stand was seriously injured by spraying in the first experiment.

Second year. Treatments 1 to 4 included Garry oats at 2 1/2 bu/A with an application of 1/3 lb/A of 2,4-D ester when the crop was in the 5-leaf stage for treatments 2 to 4 and a postharvest application of 1 lb/A of 2,4-D ester or postharvest cultivation in treatments 3 and 4. Treatments 1 to 4 prevented leafy spurge from increasing and stands were reduced slightly by those that included an application of 2,4-D.

Corn was planted in treatments 5 to 8. It was cultivated lengthwise twice and crosswise once during the season. One-third lb/A of 2,4-D ester was applied shortly after the first cultivation in treatments 6 to 8. Leafy spurge stands appeared to have been reduced by treatments 5, 6, and 8, indicating the 2,4-D application was not necessary for killing seedlings or 1-year-old plants.

In treatments 9 to 12, the alfalfa appeared to have reduced the stand almost 50 percent. In treatments 13 to 20, a crop of sudangrass in the first experiment, and a crop of sweetclover in the second experiment, appeared to be superior to the alfalfa. In the second experiment, sweetclover was harvested for seed in treatments 13 to 16. The sweetclover in treatments 17 to 20 was plowed during late June, tandem disked once and cultivated three times during July, August and September.

Third year. All treatments included a crop of Selkirk wheat. In each of the five rotations one treatment (1, 5, 9, 13, 17) did not include any 2,4-D or late summer cultivation. One treatment (2, 6, 10, 14, 18) in each rotation included an application of 1/2 lb/A of 2,4-D ester when the wheat was in the 5-leaf stage. The remaining treatments included an identical application of 2,4-D and a postharvest application of 1 lb/A of 2,4-D ester (3, 7, 11, 15, 19) or a plowing in early August and two cultivations in August and September (4, 8, 12, 16, 20). All other treatments included plowing during early September.

The stand of leafy spurge increased from 0.5 to 1.1 plants per square yard for treatments 1, 5, 9, 13 and 17 and from 0.3 to 0.5 for treatments 3, 7, 11, 15 and 19 but remained constant on plots receiving other treatments. These results indicate that the optimum treatment included a spraying of 2,4-D in the grain, without a fall operation.

Fourth year. All treatments included a crop of S.D. 270 corn that was cultivated three times. Three treatments in each rotation included an application of 1/3 lb/A of 2,4-D ester shortly after the first cultivation. The 120 plots receiving this treatment contained an average of 0.3 plants per square yard after 3 years, and 0.4 after 4 years.

The fourth treatment in each rotation did not include the application of 2,4-D. These 40 plots contained an average of 1.1 plants per square yard at the end of the third year, and 2.9 plants at the end of the fourth. These results indicate that the 2,4-D treatment was helpful in reducing the rate of reinfestation by leafy spurge.

Crop yields. In the first experiment, Mo-0-205 oats unsprayed, sprayed with 1/4 lb/A of 2,4-D amine, or with 1/3 lb/A of 2,4-D ester, yielded 62.1, 62.9, and 62.3 bu/A, respectively. In the second experiment, Garry oats produced 71.5, 73.3, 67.1, and 77.9 bu/A on plots that were unsprayed, treated with 1/4 lb/A of 2,4-D amine, 1/3 lb/A of 2,4-D ester, or 1 lb/A of 4-(2,4-DB), respectively. Unsprayed Selkirk wheat yielded 23.9 and 16.8 bu/A in two experiments, while that sprayed with 1/2 lb/A 2,4-D ester produced 19.5 and 16.4 bu/A. S.D. 270 corn yielded 19.1 and 51.5 bu/A when unsprayed and 23.4 and 46.5 bushels when sprayed with 1/3 lb/A of 2,4-D ester in two experiments.

Summary. Seven treatments allowed reinfestation of more than 1 plant per square yard. Four of them did not include 2,4-D application any of the 4 years. Plots that received 2,4-D each of the 4 years contained 0.4 plants per square yard with a range of 0 to 1.9 plants. This statement can be repeated for plots receiving the 15 treatments that utilized 2,4-D the fourth year and included sprayed small grain, sprayed corn or a forage crop during previous years.

Discussion

Although the results from various combinations of cultivation, cropping and spraying are essentially the same as reported previously (15), this study shows that the various combinations can be incorporated into profitable crop rotations.

The authors' choice of treatments include treatments 5, 8, 15, 25, 29 and 32 in Table 1. Treatment 8 might have been improved by the use of 2,4-D in the corn crop. All treatments might have been improved by a post-tasseling application of 2,4-D in the corn with a high-clearance sprayer. Such treatment would apply constant pressure to the leafy spurge for a 4-year period. Although 2,4-D was used several times in each rotation, intensive cultivation, which appeared to be more effective, was used whenever possible. These treatments are less dependent on the effectiveness of an herbicide than other similar treatments. They should be more effective in eliminating a population containing strains that are resistant to the herbicide.

The variety of control methods can be increased by the use of 2,3,6-TBA or amitrole. The substitution of the first year of treatment 7 of Experiment 1 in Table 2 for the small grain year of any treatment in Table 1 should improve that treatment. Likewise the substitution of the first year of treatments 4, 7 or 13 of Experiment 2 in Table 2 for the fourth year of any treatment in Table 1 should improve that treatment. In areas where 2,3,6-TBA injures corn, it may be advisable to use treatments 4 or 13 (Table 2) in preference to treatment 7. Treatment 8 (Table 1) did not leave the soil bare over winter. Treatment 5 and 15 left it bare over winter after the third year. Treatment 32 left it bare after the second and third years and treatment 29 left it bare over three winters. Therefore, soil erosion problems as well as crop utilization need to be considered when selecting the program to follow.

The authors believe that a cultivator with sharp 24- to 30-inch sweeps can be substituted for the plow and cultivator used in these treatments. This implement would aid in reducing the stand of weeds and leave a stubble mulch on the soil surface. If application of 2,3,6-TBA is substituted for fall cultivation after small grain harvest, it is doubtful if a wide-sweep cultivator could be substituted for the late summer plowing required for effective weed control with 4 to 6 lb/A of that herbicide.

Conclusions

1. Leafy spurge can be almost completely eliminated while utilizing crop sequences adapted to South Dakota without causing serious soil deterioration.
2. Leafy spurge stands can be materially reduced by several combinations of crops, cultivation and herbicides:(a) three cultivations, a close-drilled crop of sudangrass and fall cultivation, (b) a short season of intensive cultivation and an August seeding of Alfalfa or bromegrass, (c) spring application of 4 to 6 lb/A of 2,3,6-TBA or 6 to 8 lb/A of amitrole, plowing 10 days later, and a corn crop cultivated three times and sprayed with 1/3 lb/A of 2,4-D ester 1 week after first cultivation, or (d) a small grain crop sprayed with 1/3 pound 2,4-D ester, and a postharvest application of 4 to 6 lb/A of 2,3,6-TBA, and plowing 10 days later.
3. Leafy spurge stands can be slightly reduced by: (a) spraying in bromegrass with 1 lb/A of 2,4-D ester in June and again in mid-August, and (b) spraying in small grain with 1/3 to 1/2 lb/A of 2,4-D ester and cultivating three to four times after harvest.
4. Leafy spurge can be held in check by: (a) spraying in small grain or corn with 2,4-D ester, (b) a good stand of alfalfa, (c) postharvest application of 2,3,6-TBA or amitrole after having used the same herbicide before planting corn the previous year.

5. These various combinations of cropping, cultivation and spraying can be incorporated into numerous 4-year programs that will eliminate leafy spurge if one of the combinations that materially reduces stands is used 1 or 2 years in the program.
6. Reinfestation by seedlings can be prevented while using soil building crop rotations. Legume crops (alfalfa or sweetclover) or the annual application of 2,4-D required to control annual broad-leaved weeds in small grain or corn will kill leafy spurge seedlings.

Literature cited

1. Arny, A. C. 1932. Variations in organic reserves in underground parts of five perennial weeds from late May to November. Minnesota Agr. Exp. Sta. Bul. 84.
2. Bakke, A. L. 1937. Control of leafy spurge, *Euphorbia Esula* L. Iowa Agr. Exp. Sta. Bul. 222.
3. Bakke, A. L. 1939. Experiments on the control of European bindweed. Iowa Agr. Exp. Sta. Bul. 259, pp. 367-440.
4. Bakke, A. L. Gaessler, W. G., and Loomis, W. E. 1939. Relation of root reserves to control of European bindweed *Convolvulus arvensis* L. Iowa Agr. Exp. Sta. Res. Bul. 254.
5. Bakke, A. L. Gaessler, W. G., Plutz, L. M., and Salmon, S. C. 1944. Relation of cultivation to depletion of root reserves in European bindweed at different soil horizons. Jour. Agr. Res. 69:137-47.
6. Craig, H. A. 1957. A leafy spurge eradication program. Proc. NCWCC 14:18-19.
7. Franzke, C. J., and Hume, A. N. 1936. Field bindweed and control methods for South Dakota. South Dakota Agr. Exp. Sta. Bul. 305.
8. Frazier, J. C. 1941 Advantages of a fourteen-day interval of cultivation for control of field bindweed. Am. Jour. Bot. 28:125..
9. Frazier, J. C. Nature and rate of development of root system of *Convolvulus arvensis*. Bot. Gaz. 104:417-25. 1942.
10. Hanson, H. C., and Rudd, Velva E. 1933. Leafy spurge–life history and habits. North Dakota Agr. Exp. Sta. Bul. 266.
11. Stahler, L. M. 1948. Shade and moisture factors in competition between selected crops and field bindweed, *Convolvulus arvensis*. Jour. Am. Soc. Agron. 40:490.
12. Stevens, O. A. 1950. Handbook of North Dakota Plants. North Dakota Inst. for Regional Studies. Knight Printing Co. Fargo, N. Dak.
13. Timmons, F. L. 1941. Results of bindweed control experiments at the Fort Hays Branch Station. Kansas Agr. Exp. Sta. Bul. 296.
14. Timmons, F. L. and Bruns, V. F. 1951. Frequency and depth of shoot-cutting in eradication of certain creeping perennial weeds. Agron. Jour. 43:371-5.
15. Derscheid, Lyle A., Wallace, Keith E., and Nash, Russel L. 1960. Leafy spurge control with cultivation, cropping and chemicals. Weeds 8:115-27.
16. Derscheid, Lyle A., Wicks, Gail A., and Wallace, Wilford H. 1963. Cropping, cultivation and chemicals to prevent reinfestation of leafy spurge. Weeds 11:105-111.
17. Timmons, F. L., and Bruns, V. F. 1951. Frequency and depth of shoot-cutting in eradication of certain creeping perennial weeds. Agron. J. 43:371-5.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 53-67.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

Chemical control of leafy spurge: Summary

HAROLD P. ALLEY

Professor and Extension Weed Specialist, University of Wyoming, Laramie

When considering chemical control of leafy spurge (*Euphorbia esula* L.) the nature of its infestation is of paramount importance. Leafy spurge is a very competitive and aggressive perennial plant. It has spread and increased in acreage infested indecent years from isolated areas of Wyoming to where it is reported in most every county of the state. It can be-found on the best agriculture land to the rocky slopes and hilltops of low productive rangeland sites.

Infestations range from solid stands where all other vegetation is virtually eliminated to isolated infestations which serve as a source of seed for its' spread and subsequent usefulness of additional acreages.

Even though leafy spurge infestations on grassland and rangeland sites may not be an indication of misuse, its' presence is undesirable from the standpoint of high productivity of palatable forage. To obtain the maximum sustained productivity of any pasture or rangeland site certain established practices are paramount, one of which is the control or eradication of the least productive and unpalatable species.

Since cultural practices are very expensive and in most cases not practical or adaptable to non-cultivated areas, other methods of control must be made available and utilized. Since other methods of control such as biological methods have not been satisfactory the use of selective chemicals as a means of removing the undesirable herbaceous weed has received considerable attention.

The importance and significance of the leafy spurge infestation in Wyoming can be borne out in the adoption of the "Leafy Spurge Control Act of 1978." The forty-fourth Wyoming Legislature appropriated $1.4 million for the treatment of this weed. Although $1.4 million appears to be a very large sum and the program over ambitious and doomed for failure by some, it is a shame this same foresight was not prevalent some 20 years ago, whereby the infestations could have been isolated, controlled or even eradicated then the acreage infested was only a fraction of what it now is.

The chemical control of leafy spurge can be traced from the early research reports of 1937 when sodium chlorate, creosote-kerosene, sulphuric acid, ammonium thiocyanate, potassium chlorate, kainite and barnyard manure was researched and progressing from the late forties with the introduction of the phenoxy herbicides to what compounds we possess at the present time.

It is very doubtful that new herbicides are going to be available in the near future. The proper selection, use, and understanding of what is now available, future emphasis must be directed toward increasing the effectiveness of the herbicides now available.

Phenoxy compounds

Although there are differences of opinion between researchers and control obtained with 2,4-D, formulations varying between states and even areas within states, the results obtained in Wyoming and rates of use suggested are as follows: The application of light rates of 2,4-D at 2.0 to 6.0 lb ai/A can be used with moderate success. The 2.0-lb/A rate applied at early bud stage will kill the top growth, young seedlings, and prevent seed production for that season. Rates of 4, 6 and 8 lb ai/A has been more effective than lower concentrations. However, with good growing conditions at the time of treatment, the 8 lb rate has not been significantly better than the 4 lb treatment. Where dry conditions prevail, the 8 lb rate of either the ester or amine has produced better control than lesser amounts. Repeated applications of 2 lb of 2,4-D of the ester or amine over a 4-year period has resulted in a control of 25 to 45 percent of the original stand. Two applications per year (both spring and fall) will enhance the percentage control obtained with several years repeated applications necessary to substantially reduce the stand and possibly eradicate the plant.

Heavy rates of 2,4-D amine, 20 to 40 lb ai/A, has consistently given near 80 percent control of the original stand one year following treatment, however, reinfestation occurs by the second year. Fall treatments are suggested over earlier dates of application.

Banvel (dicamba)

Low rates of dicamba are comparable in effectiveness to light rates of 2,4-D. An application rate of 6.0 to 8.0 lb ai/A are required for an average of 80 percent or greater stand reduction. Even at the higher rate of application recovery and reinfestation is almost complete within two years following application. Fall applications appear to be as effective, and in some cases, more effective than earlier treatments. Granular formulations have not appeared to be any more effective than liquid formulations and are more damaging to the associated grass species.

Tordon (picloram)

Picloram is the most consistent and effective herbicide available for control and eradication of leafy spurge. For consistent and longevity of control the 2.0 lb/A is needed. Lower rates are not as effective and reinfestation occurs in a shorter period of time and subsequent annual applications would generally be required. Fall applications of picloram are usually more consistent than spring applications. Where there have been dense stands of old foliage the granular formulation is more effective than the liquid formulation probably because of tie up of the liquid in the old vegetation reducing the amount of picloram reaching the soil. Granular formulations are more damaging to the associated grass species. Retreatment of leafy spurge seedlings with 2,4-D or light rates of dicamba or combinations of the two should be considered in an eradication program.

Roundup (glyphosate)

Glyphosate at 2.0 to 3.0 lb ai/A will effectively kill 80 to 90 percent of the leafy spurge if applied from the full bloom stage to later in the growing season. Reports of applications as late as September has been effective. Early treatments have not been as effective. Since there is no soil activity from Roundup, follow-up treatments with 2,4-D or light rates of dicamba is necessary. The use of Roundup on infested range sites is not practical because of its activity on grass, bare areas result.

New compounds

Triclopyr or Dowco 290 alone or in combination with 2,4-D has not been effective on leafy spurge.

Combinations

Combinations of dicamba/2,4-D, dicamba/Roundup, or even picloram/2,4-D are no better than the most effective herbicide at the specific rate applied.

Remarks for Table 2
General summary

Carbon County

Treatments made August 4, 1964, were square rod plots. Treatments on September 9, 1964, were applied with a ground rig and were 2 to 3 acres in size. The later treatments seemed to be more effective at the 1.0 lb/A. There was slight grass damage at 2.0 lb/A Tordon 22K and above, but not as severe to grass as Benzabor at 1 1/2 lb/sq rod.

Johnson County

Damage to the grass species were the most severe evaluated in all plots across the state. The succulence of mainly smooth bromegrass in the irrigated meadows account for the severe damage by Tordon applications.

Platte County

Readings are an average of three replications. Several chemicals and combinations resulted in outstanding control one year following treatment.

Sheridan County

Three pounds per acre of Tordon 22K was required for 100 percent control. All other locations 2 lb/A was sufficient.

General summary

Limited data indicates that fall treatments may be more effective than spring treatments.

Tordon 101 (Tordon + 2,4-D) was very effective; however, showed considerable damage to associated grass species at lower rates of picolinic acid per acre than was applied by Tordon 22K.

Tordon Granules (2% picolinic acid) was comparable to equivalent rates of Tordon 22K (acid) but seemed to be more toxic to grasses than the liquid formulations.

Remarks for Table 3

General summary

Carbon County

Leafy spurge treated at the full bloom stage of growth resulted in only fair control. The residual of all chemicals except Tritac D and 2,4-D was prevalent and increased control may be evident by next year.

Laramie County

All treatments included in the demonstration resulted in outstanding control. Leafy spurge seedlings were common in the Banvel treated plots indicating short soil residual.

Johnson County

Plots established in 1964 and evaluated two years following application showed outstanding control. Grass plants in the Tordon 22K treated areas had recovered from the chemical damage recorded in 1965.

Platte County

Considerable variation in leafy spurge control was evident between replications. Approximately one-half of the plots were on native grassland and half on railroad-rights-of-way.

Sheridan County

Benzabor at 1.5 lb/sq rod, Tordon beads at 0.75 and 1.25 lb/sq rod, and Tordon 22K at 1.0 and 3.0 lb/A gave 92 to 100 percent control. All rates of Tordon 22K damaged the native grass species.

Table 1. Chemical control of leafy spurge (1959-60).

	Plots Established June 2, 1959		
Treatment	Rate[1]	Control & Remarks 1960[2]	
Chlorea Gran. 3	4 lb/sq. rd.	80	Bare spots
Chlorea Gran. 3	6 lb/sq. rd.	90	Few plants left
Chlorea + 2,4-D	5 lb/sq. rd.	99	Few plants left
Chlorea + 2,4-D	10 lb/sq. rd.	99	Few plants left
Atlacide + 2,4-D	5 lb/sq. rd.	95	Few plants left
Atlacide + 2,4-D	10 lb/sq. rd.	98	Few plants left
Monuron	1/4 lb/sq. rd.	75	Plants yellow & damaged
Monuron	1/2 lb/sq. rd.	75	Plants yellow & damaged
Diuron	1/4 lb/sq. rd.	50	Not effective
Diuron	1/2 lb/sq. rd.	50	Not effective
Fenuron	1 lb/sq. rd.	50	Not effective, yellow plants
Fenuron	2 lb/sq. rd.	88	Yellow regrowth
Simazine	1/8 lb/sq. rd.	30	Not effective
Simazine	1/4 lb/sq. rd.	50	Not effective
Atrazine	1/8 lb/sq. rd.	99	Few plants remaining
Atrazine	1/4 lb/sq. rd.	99	Few plants remaining
Ureabor	2 lb/sq. rd.	97	Few plants remaining
Ureabor	4 lb/sq. rd.	98	Few plants remaining
Ureabor	6 lb/sq. rd.	99	Few plants remaining
Benzabor	2 lb/sq. rd.	93	Some regrowth
Benzabor	4 lb/sq. rd.	95	Some regrowth
D. B. Granules	3.3 lb/sq. rd.	99	
D. B. Granules	6.6 lb/sq. rd.	100	
2,4-D amine	40 lb/sq. rd.	97	Plants remaining are healthy
2,4-D amine	80 lb/sq. rd.	97	Plants remaining are healthy
ATA	8 lb/sq. rd.	0	Not effective
ATA	12 lb/sq. rd.	0	Not effective
Amitrol-T	8 lb/sq. rd.	0	Not effective
Amitrol-T	12 lb/sq. rd.	0	Not effective
Fenac Liquid	8 lb/sq. rd.	90	Leaves malformed
Fenac Liquid	16 lb/sq. rd.	90	Leaves malformed, good grass
TBA	20 lb/sq. rd.	70	Vigorous regrowth
TBA	40 lb/sq. rd.	95	Good grass

Table 1. Continued

	Plots Established Sept. 10, 1959		
Treatment	Rate[1]	Control & Remarks 1960[2]	
Chlorea Gran. 3	4.5 lb/sq. rd.	100	
Chlorea Gran. 1	9 lb/sq. rd.	98	
Chlorea Gran. 1	6 lb/sq. rd.	95	
Ureabor	6 lb/sq. rd.	99	
Ureabor	4 lb/sq. rd.	96	
Atlacide + 2,4-D	10 lb/sq. rd.	99	Few scattered small plants
Benzabor	3 lb/sq. rd.	100	Grass in plot
Benzabor	1.5 lb/sq. rd.	98	Few remaining plants
Monuron	1/2 lb/sq. rd.	50	Spurge chlorotic
Monuron	1/4 lb/sq. rd.	50	Spurge chlorotic
Atrazine	20 lb/sq. rd.	50	Spurge chlorotic
Atrazine	40 lb/sq. rd.	96	Spurge chlorotic
ATA	8 lb/sq. rd.	85	Healthy spurge
ATA	4 lb/sq. rd.	40	Healthy spurge
Fenac Powder	20 lb/sq. rd.	99	Good grass
Fenac Powder	10 lb/sq. rd.	95	Good grass
Fenac Powder	5 lb/sq. rd.	60	Good grass
Fenac Gran.	400 lb/A	99	Grass chlorotic
Fenac Gran.	200 lb/A	70	
Fenac Gran.	100 lb/A	50	
Amitrol-T	8 lb/sq. rd.	22	Some chlorosis
Amitrol-T	4 lb/sq. rd.	25	Some chlorosis
Fenac Liquid	20 lb/sq. rd.	99	
Fenac Liquid	10 lb/sq. rd.	95	
Fenac Liquid	5 lb/Sq. rd.	80	
2,4-D amine	80 lb/sq. rd.	99	Good grass
2,4-D amine	40 lb/sq. rd.	99	Good grass
TBA	20 lb/sq. rd.	90	Residual activity
TBA	10 lb/sq. rd.	85	Residual activity

[1]Rate per acre expressed in pounds active ingredient per acre unless otherwise indicated.
[2]All plots torn up by new ranch owner in 1961.

Table 2. Leafy spurge summary - 1965 evaluations

Chemical and Rate/A or Sq. Rod[1]			Location of Plots - County Percent Control Carbon[2]	Johnson	Platte	Sheridan	Percent average control
Tordon 22K	1.0		99	94	96	90	94
Tordon 22K	2.0		100	100	100	98	99
Tordon 22K	3.0		100	100	100	100	100
Tordon 22K	4.0		100	100	100	100	100
Tordon Granules	0.3125	lb/sq rod			97		97
Tordon Granules	0.6125	lb/sq rod			100		100
Tordon Granules	0.75	lb/sq rod	100				100
Tordon Granules	0.9375	lb/sq rod			100		100
Tordon Granules	1.25				100		100
Tordon Granules	1.5		100				100
Tordon 101	1.3	gal			99		99
Tordon 101	2.6	gal			100		100
Tordon 101	3.9	gal			100		100
Tordon 101	5.2	gal			100		100
Benzabor	0.75	lb/sq rod			100		100
Benzabor	1.5	lb/sq rod	98	50	100		83
Banvel	5.0				97		97
Banvel	10.0				100		100
Banvel	15.0				100		100
2,3,6TBA	10.0				100		100
2,3,6TBA	20.0				100		100
Tritac D	4.0	gal			80		80
Tritac D	5.0	gal		85		85	85
Tritac D	6.0	gal			100		100
Tritac D	7.0					90	90
Tritac D	8.0				100		100
Fenac Liquid	5.0				75		75
Fenac, Liquid	10.0				99		99
Fenac Liquid	15.0				100		100
Fenac Granules	0.5	lb/sq rod			99		99
Fenac Granules	1.0	lb/sq rod			100		100
Fenac Granules	1.5	lb/sq rod			100		100
2,4-D amine	6.0				75		75
2,4-D amine	20.0				85		85
2,4-D amine	40.0				90		90
2,4-D LVE	2.0				20		20
2,4-D LVE	4.0				20		20
2,4-D LVE	6.0				60		60
2,4-D LVE + X-77	2.0				30		30
2,4-D LVE + X-77	4.0				70		70
2,4-D LVE + X-77	6.0				80		80
Dacamine	6.0				65		65

[1]Plots established in spring or fall of 1964. Evaluated 1965. Rate/A in pounds active per acre unless otherwise stated.
[2]Both spring and fall treatments included in evaluation.

Table 3. Leafy spurge summary - 1966 evaluation.

Chemical and Rate/A or Sq. Rod[1]			Location of Plots-County Percent Control					Range of control
			Carbon*	Johnson**	Laramie*	Platte**	Sheridan*	
Tordon 22K	1.0		85	97	100	82	96	82-96
Tordon 22K	2.0		95	99	100	99	100	95-100
Tordon 22K	3.0			100		100		100
Tordon 22K	4.0					100		100
Tordon Granules	0.3125					99		99-100
Tordon Granules	0.5	lb/sq rd			100			100
Tordon Granules	0.6125	lb/sq rd				100		100
Tordon Granules	0.75	lb/sq rd	75	96	100		99	75-100
Tordon Granules	0.9375	lb/sq rd				100		100
Tordon Granules	1.25	lb/sq rd	80	100	100	100	100	80-100
Tordon 101	1.0	gal			99			99
Tordon 101	1.3	gal				90		85-95
Tordon 101	2	gal			100			100
Tordon 101	2.6	gal				96		95-98
Tordon 101	3.9	gal				99		98-100
Tordon 101	5.2	gal				100		100
Benzabor	0.75	lb/sq rd				90		80-100
Benzabor	1.5	lb/sq rd	30	93		98	92	97-100
Banvel	5.0				90	77		70-90
Banvel	10.0				97	90		90-97
Banvel	15.0					96		95-100
2,3,6TBA	10.0					96		95-98
2,3,6TBA	15.0					98		98
2,3,6TBA	20.0					100		100
Tritac D	5.0			85				85
Tritac D	6.0		40		99			40-99
Tritac D	8.0				100	50		20-100
Tritac D	12.0					94		90-98
Tritac D	16.0				98			98

Table 3. Continued.

Chemical and Rate/A or Sq. Rod[1]		Location of Plots-County Percent Control					Range of control
		Carbon*	Johnson**	Laramie*	Platte**	Sheridan*	
Fenac Liquid	5.0				50		10-90
Fenac Liquid	10.0				90		85-95
Fenac Liquid	15.0				99		99-100
Fenac Granules	0.5 lb/sq rd				97		95-100
Fenac Granules	1.0 lb/sq rd			100	100	85	85-100
Fenac Granules	1.5 lb/sq rd				100		100
2,4-D amine	6.0				20		10-30
2,4-D amine	20.0				30		10-50
2,4-D amine	40.0				79		60-98
2,4-D LVE	2.0				57		15-99
2,4-D LVE	4.0				47		0-95
2,4-D LVE	6.0	70			25		10-70
2,4-D LVE + X-77	2.0				5		0-10
2,4-D LVE + X-77	4.0				17		10-25
2,4-D LVE + X-77	6.0				20		0-40
Dacamine	6.0				15		0-30

*Readings one year following treatment.
**Readings two years following treatment.
[1]Rate per acre expressed in pounds active ingredient unless otherwise states.

Table 4. Leafy spurge control three years following treatment. Platte County.

		% Control			
Chemical[1]	Rate/A[2]	67/11/65	5/23/66	8/16/67	Remarks
Banvel	5.0	97	77	20	
Banvel	10.0	100	90	20	
Banvel	15.0	100	96	50	Moderate grass damage
2,3,6TBA	10.0	100	96	70	
2,3,6TBA	15.0	100	98	98	Grass thinned
2,3,6TBA	20.0	99	100	90	Grass thinned
Fenac Liquid	5.0	75	50	0	
Fenac Liquid	10.0	98	90	60	
Fenac Liquid	15.0	100	99	98	Some grass damage
Fenac Granules	0.5 lb/sq rod	98	97	95	
Fenac Granules	1.0 lb/sq rod	100	100	95	Grass damage
Fenac Granules	1.5 lb/sq rod	100	100	100	Grass damage
Tritac D	8.0	78	50	70	
Tritac D	12.0	99	94	65	
Tritac D	16.0	99	98	90	
Benzabor	0.75 lb/sq rod	100	90	90	
Benzabor	1.5 lb/sq rod	100	98	100	
Tordon 22K	1.0	96	83	55	
Tordon 22K	2.0	100	99	98	
Tordon 22K	3.0	100	100	100	
Tordon 22K	4.0	100	100	100	
Tordon 101	1.3 gal/A	99	90	100	
Tordon 101	2.6 gal/A	99	96	100	
Tordon 101	3.9 gal/A	100	99	100	Grass damage
Tordon 101	5.2 gal/A	100	100	100	Grass damage
Tordon Granules	0.3125 lb/sq rod	97	99	100	
Tordon Granules	0.625 lb/sq rod	100	100	95	
Tordon Granules	0.9375 lb/sq rod	100	100	100	
Tordon Granules	1.25 lb/sq rod	100	100	100	
Dacamine	6.0	65	15	0	
Amitrol T	8.0	50	15	25	Grass damage

[1]Plots established May 15, 1964. Carrier 40 gpa water.
[2]Rate/A in pounds per acre active ingredient unless otherwise stated.

Table 5. Leafy spurge control. Johnson County. Established June 25, 1975. Full bloom. Soil-loam. Carrier-water 40 gpa.

		% Control		
Treatment	Rate lb ai/A	6/15/76	6/17/77	Remarks (1976)
Triclopyr	1.5	0	0	No stand reduction
Triclopyr	3.0	0	0	Knockdown only
Triclopyr + 2,4-D A	1.5 + 1.0	0	0	Knockdown only
Triclopyr + 2,4-D A	3.0 + 1.0	0	0	Knockdown only
Dowco 290	1.0	0	0	Poor activity
Dowco 290	2.0	0	0	Poor activity
Dowco 290 + 2,4-D A	1.0 + 1.0	0	0	Poor activity
Dowco 290 + 2,4-D A	2.0 + 2.0	0	0	Poor activity
Picloram	1.0	98	80	Few small spurge
Picloram	2.0	98	90	Smooth brome prostrate
Picloram + 2,4-D	1.0 + 2.0	96	80	Few small spurge
Picloram + 2,4-D	2.0 + 4.0	98	90	Smooth brome prostrate
Picloram + Dicamba	0.25 + 2.0	80	0	Healthy spurge
Picloram + Dicamba	0.5 + 2.0	88	0	New regrowth
Dicamba	2.0	20	0	
Dicamba	4.0	50	0	No grass damage
Dicamba	8.0	80	0	No damage to grass
Vel-5027	4.0	50	0	Knockdown early
Vel-5027	8.0	60	0	Knockdown early
Dicamba + 2,4-D	1.0 + 3.0	70	0	Recovery later
2,4-D A	6.0	40	0	Spurge healthy
2,4-D A	20.0	80	0	Spurge healthy
Glyphosate	2.0	80	0	Good early-no residual
Glyphosate	3.0	85	0	Good early-no residual
Glyphosate + 2,4-D A	1.0 + 2.0	50	0	Good knockdown-no residual

Table 6. Leafy spurge control- Johnson County-Fred Brug Ranch. Established May 20, 1965.

Chemical	Rate/A[1]	% Control 5/17/66	% Control 5/18/67	Remarks
Tordon 22K-	1.0	96	98	Hounds tongue in plots
Tordon 22K	2.0	100	100	
Tordon 22K	3.0	100	100	
Tordon Beads	0.75 *lb/sq* rod	99	99	Bluegrass not damaged
Tordon Beads	1.25 *lb/sq* rod	100	100	Bluegrass not damaged
Benzabor	1.5 lb/sq rod	92	98	
2,4-D LVE	6.0	45	40	

[1]Rate per acre expressed as pounds active ingredient unless otherwise stated.

Table 7.

Chemical	Rate/A[1]	% Control 7/10/68	Remarks
Tordon 101	1 gal	50	Healthy leafy spurge
Tordon 101	2 gal	85	Small leafy spurge plants
Tordon 212	0.5 gal	40	Healthy leafy spurge
Tordon 212	1.0 gal	65	Small leafy spurge plants
Tordon Beads	0.75 lb/sq rod	100	Bluegrass browned
Tordon Beads	1.0 lb/sq rod	100	Bluegrass browned
Tordon 22K	1.0	50	Healthy leafy spurge plants
Tordon 22K	2.0	96	Small leafy spurge plants

[1]Rate per acre expressed as pounds active ingredient unless otherwise stated.

Table 8. Leafy spurge control. Carbon County. Established July 12,28. Raju, M.V.S., R.T. Coupland, and T.A. Steeves. 1966. On the occurrence of root buds on the perennial plants in Saskatchewan. Can. J. Bot. 44:33-37.

Herbicide	Rate lb ai/A	% Control[2]	Observations
Picloram	2.0	100	30% reduction of grass
Picloram	3.0	100	50% reduction of grass
Picloram	4.0	100	70% reduction of grass
Picloram + 2,4-D	2.0 + 4.0	100	30% reduction of grass
Picloram + 2,4-D	3.0 + 6.0	100	50% reduction of grass
Picloram 2% beads	2.0	100	20% reduction of grass
Picloram 2% beads	3.0	100	50% reduction of grass
Picloram 10% pellets	2.0	95	Bare spots in plots
Picloram 10% pellets	3.0	100	Bare spots in plots
Picloram + 2,4,5-T	2.0 + 4.0	98	Some grass damage
Picloram + 2,4,5-T	3.0 + 6.0	100	Some grass damage
Dicamba	6.0	95	Good grass cover
Dicamba	8.0	99	Good grass cover
Dicamba 10% granules	6.0	80	Bare spots-poor coverage
Dicamba 10% granules	8.0	90	Bare spots-poor coverage
Dicamba + 2,4-D	4.0 + 12.0	90	Good grass cover
Dicamba + 2,4-D	6.0 + 18.0	90	Good grass cover
Dowco 290 (M-3972)	2.0	50	Good grass cover
Dowco 290 (M-3972)	3.0	50	Good grass cover
Glyphosate + Dicamba	1.0 + 2.0	50	Good grass cover
Glyphosate + Dicamba	1.0 + 3.0	50	Good grass cover
Glyphosate	2.0	50	30% reduction of grass
Glyphosate	3.0	80	50% reduction of grass
DPX-1108	4.0	0	
DPX-1108	6.0	40	
R-40244	2.0	0	

[1]Herbicides applied July 12, 1977 to pasture heavily grazed by sheep. Grass less than 1-in. leaf height.
[2]Evaluated July 14, 1978.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 68-69.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

Aerial infrared imagery of leafy spurge (*Euphorbia esula*)

DAVID W. ARMSTRONG III

Botanist

During the last several years an increasing awareness of the nature and extent of noxious plants has developed in Montana and surrounding areas. With this increase in awareness have come the strident calls for help and a feeling that something must be done to stem the invasion.

Leafy spurge (*Euphorbia esula*) has received nearly all of the attention of those individuals concerned with noxious weed control. Concerned parties cite numerous examples of the extent and pervasiveness of this plant. Estimates of the acres populated by leafy spurge in Montana range from 200,000 to nearly 600,000 acres depending on which agency or individual did the survey.

Beginning in 1975, we began to come to grips with the need to inventory our noxious weed problems. An inventory accomplishes several things:

1) The extent, nature, and locations of the target populations can be delineated and placed on maps. These maps allow interested parties to determine the number of acres of the plant and where populations of these plants can be found.

2) Populations of noxious plants can be recorded in terms of "net" and "gross" acres. Generally, plants of all kinds do not grow in solid mats of vegetation, but are distributed over an area groups or as individual plants. The total area that a surveyor may reasonably expect to find plants of the target population is referred to as the "gross" area. This figure provides and indication of labor required to search an area for a designated plant. The area in 1/100th acre (400 sq. ft.) increments, when designated plants from a single (gross) area are grouped together as a whole constitutes "net" acreage. Net acreage can be used to determine the amount of chemical required to treat a target area. Use of these two terms could be very useful for providing a standardized basis for reporting data about target plants.

3) Weed control is fraught with the "other guy" syndrome. The weed problem could be solved if only the "other guy" would control his weeds. Inventories allow each afflicted party to assess the extent of the problem on his land, his neighbor's land,

land in the county, land in state or even other states. Once people understand the extent of the problem and what they must deal with, then they are more likely to cooperate with a program.

4) Inventories are vital to the development of management plans. No one believes that we can solve the management of noxious plants with a one time program. Management of noxious plant requires planning, time, persistence and evaluation. Inventories are vital to all of these.

5) Often noxious plants afflict individuals and agencies alike. With the inventory completed and management plans written, money is more likely to be available to assist in solving the problem. Those that are asking private landowners and the public to pay must demonstrate an adequate and reasonable need for the money.

We have developed a method of inventorying leafy spurge using aerial photographic imagery. When leafy spurge is fully in bloom an image can be obtained on Kodak 2443 false color infrared film, which can be characterized as a ‘‘hot pink’’. This signature is characteristic of leafy spurge at full bloom and is not easily confused with any other plant. We used a 35 mm system described by Heyer (73, 78) to develop this signature. For mapping purposes we use the large format 9 X 9 2443 film. Our studies indicate that a scale of 1:24,000 (3 inches/mile) or larger are necessary to adequately image small leafy spurge patches. We have successfully imaged 100 sq. foot patches of leafy spurge at 1:24,000 scale. The best time to Image leafy spurge is between the 2nd week of June to the 2nd week of July.

In summary, leafy spurge can successfully be inventoried by using the following:

- Film: Kodak 1443 color infrared
- Filter: Yellow 12
- Film scale: 1:24,000 or larger
- Date: 2nd week of June - 2nd week of July
- Phenology: Leafy spurge should be in full “bloom’’ and growing vigorously.

Bibliography

1. Meyer, M. P. 1973. Operating Manual - Montana 35 mm Aerial Photography System. IARSL Research Report 73-3. College of Forestry, Univ. of Minn., St. Paul, Minn.

2. Meyer, M. P., P. D. Grumstrup. 1978. Operating Manual - Montana 35 mm, Aerial Photography System. 2nd Revision. IAFHE RSL Research Report 78-1. Univ. of Minn., St. Paul, Minn.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. pp. 70-78.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

Workshop session: Summaries

Leafy spurge the plant

I. Areas of research needed (listed according to priority):

A. To investigate the taxonomy of leafy spurge; including morphological, physiological, biochemical and ecological differences, with special emphasis on responses to environmental stresses and herbicide tolerance.

B. To investigate basic root physiology and biochemistry; including bud dormancy and viability, translocation of food reserves and applied chemicals and the role of endogenous plant growth regulators.

C. To study the community structure, competitiveness, infestation, mechanisms and possible allelopathy of leafy spurge.

D. To investigate various aspects of seed biology of leafy spurge; including dormancy, viability, vigor, transport or distribution mechanisms seed development and biochemistry.

E. To conduct basic investigations into the photomorphology and photochemistry of leafy spurge.

II. Participating research organizations:

Coordinated research efforts of the following agencies are suggested:

A. State Experiment Station.

B. SEA-AR.

C. Forest Service Research.

D. Agricultural chemical industry.

III. Interaction with other leafy spurge interest groups:

A. Provide basic knowledge of leafy spurge biology to support practical control programs.

B. Incorporate unusual field observations on morphology, ecology, and treatment responses into basic studies on leafy spurge biology.

C. Develop close cooperation with chemical, biological and cultural control phases of the leafy spurge control program.

D. Participate in additional regional leafy spurge research workshops to be held at three to five year intervals.

Social and economic impacts of the leafy spurge problem

Dr. Larry Mitich, Chairman

Questions and concerns considered by our workshop session.

1. Encourage biological control research work in European countries where spurge grows naturally–send researchers to the original source.
2. Biological control should continue to be a joint (cooperative) effort between U.S. and Canada.
3. An overall research review of literature is needed on work done to date to avoid unnecessary and expensive overlap.
   A. More people are needed to complete annotated list of work done on spurge.
4. Acceleration should be a key feature of the most promising aspects of the leafy spurge control programs since the weed spreads so fast.
   A. Needed are ways to compress research time.
   B. A recent research facilities (like the ASU Lab at Fargo) need to be fully utilized.
   C. Need more people and locations in key states to conduct biological control and other research.
5. An inventory is needed so the actual scope of the spurge infestation can be determined.
   A. The California concept of net and gross acreage of weed infestations has been successful and valuable.
   B. The gross and net acres of infestation of 150 weeds in California are determined every four years through the program.
   C. Who controls or owns the infested land--federal, state, counties, townships, private, etc. must be known. 1. Solving the problem may be more effective and less costly on this basis.
   D. Needed is uniform evaluation procedure so that a given infestation in one state could be compared realistically to an infestation in another state.

E. The federal and state governments may not be well informed on the leafy spurge problem.

6. In Canada, government assistance programs for leafy spurge has kept the weed from spreading the extent of infestation hasn't changed in 20 years.

7. The anti desertication program is a new $100 million Federal Program proposed for the southwestern U.S. and Mexico to study the social and economic impact of land turning to desert.

   A. We should try for a similar program on an international basis between the U.S. and Canada to show how no control can affect the standard of living and the total social-economic impact.

   B. Needed is a unified approach for a comprehensive control program.

8. We must realize the farmers' financial problem in controlling spurge.

   A. The farmers need monetary assistance.

   B. In N.D. attempts to raise money by mill levy have failed to pass repeatedly.

   C. A possible source of revenue is the Carlson-Foley Act.

9. The farmers and public need to be educated on the severity and social impact of the spurge problem.

   A. Efforts have been made but still many farmers are not responding.

10. Recommendations:

   A. Needed first is an inventory to determine the extent and location of the problem.

   B. Evaluate research and improve what we have already.

   C. Conduct educational programs for the rural and urban communities perhaps a leafy spurge pilot program is needed.

   D. Evaluate new techniques--allow wildlife and other agencies to get involved.

   E. Study ecological aspects--what species move in when spurge is removed?

   F. Need better exchange of ideas did research between states.

   G. Need more personnel on extension weed control and grassland management.

Biological control of leafy spurge: Workshop session

Chairman: Dr. Ed Balsbaugh, Jr.

The workshop session on biological control of leafy spurge commenced at 3:30 p.m. in the Dresden Boom with approximately 20 persons in attendance. Participants included interested lay-persons, representatives from the pesticide industry, university research personnel, and representatives of regulatory or research agencies from various state, federal and local governments. Thus there was a broad basis for participation.

The chairman opened the workshop session by recognizing the attendance of Dr. Peter Harris, invited guest speaker of the earlier formal session. He also reminded the participants of the objectives of the Symposium emphasizing objective 4, which particularly is apropos to the biological control area, viz. "Determine how various agencies and organizations can coordinate their work on needed basic and applied research to manage leafy spurge."

Dr. Harris began the discussions by stating 5 of his conclusions concerning the biological control of leafy spurge. "1. Leafy spurge is a good candidate for biological control. 2. Large expenditures for the control of leafy spurge or for research on it cannot be justified without better data on the present and future loses from the weed. I suspect that in part it is a matter of consolidating known information already available. 3. Biological control of leafy spurge would be easier if we could recognize and know exactly where to find the European counterpart of North American leafy spurge. 4. A major acceleration in the biological control of leafy spurge would require the addition of one to two scientist years for a minimum of 5-10 years. One large sum expenditure for one year would not accomplish too much. 5. At the present time there are two agencies in North America directly involved in the biological control of leafy spurge with several other agencies assisting with funding. If more agencies become directly involved, I suggest that a coordinating committee be formed to avoid needless duplication.''

The ensuing discussions concerned points in two general areas–1. Basically technical items on biological control and 2. Financial considerations. These two points often interacted closely.

Dr. John Pickle of Velsicol Corporation asked Dr. Harris two questions: a. ''What is an economic threshold for leafy spurge, and b. What are the potentials of any given insect or plant pathogen for successful biological control?" The response of Dr. Harris was that economic thresholds differ at different sites. He compared infested parks with rangeland. One level of infestation might be tolerated at the one site, but not the other. Control of seed spread was questioned by Dr. Pickle because of the potential for rapid dispersal along waterways. Dr. Harris responded that biological control agents can reduce seed production by reducing the vigor of the plants. He gave the example that in Saskatchewan musk thistle is now reduced to 10% of its former range via the use of insect seed feeders. Drs. Harris and Pickle debated the economic thresholds of leafy spurge on grazing land. Dr. Harris said that it really does not compete with other plants that much in that it is restricted to gullies and poorer land. Dr. Pickle on the other hand, cited Harold Alley and L. 0. Baker's work in which they claimed 300% increase in productivity of rangeland where leafy spurge had been controlled. It was concluded that cost-benefit ratios must be considered. Economic thresholds will vary at different sites. Infestations must be reduced to "tolerable levels" since biological control does not mean eradication.

It was asked, "What is the cost of applying biological control?'' Dr. Harris responded that successful biological control projects have cost $2 million, each, which includes all expenses for a multiyear project and all organisms tried. The average number of control organisms per successful biological control project has been four.

Where might additional money best be spent for biological control efforts? Would additional quarantine facilities be helpful? Right now there are 3 quarantine facilities in North America: one at Regina, Saskatchewan, one at Albany, California, and one in Virginia. Dr. Harris thought that additional funds would best be spent to support additional screening of potential insects in Europe. There are two organizations that can be used there. You can put money into the U.S.D.A. laboratory based in Rome, Italy, or the Commonwealth Institute for Biological Control, based in Switzerland. If different states want to get involved, they could attach a person to either of these labs. For plant pathogens, a pathologist microbiologist could be attached to the pathogen quarantine facility at Fort Dietrich, Maryland, where he could screen pathogens, many of which are already on hand in storage. Dr. Harris indicated interesting possibilities for plant pathogens because they can be applied by spraying--as done with chemicals--and they will be extremely host specific to the target organism. They could be sprayed on w1ldlife refuges, for example. Costs for screening plant pathogens are comparable to screening insects--i.e. about $100,000/ scientist year.

Assuming a new insect becomes available, how many locations should be considered for the initial releases? Dr. Harris responded that at first low numbers are maintained in the laboratory and a limited release is made from these. If these become established, then additional distributions can be made from that site. Fifty-fold increase can be expected per year from successful establishments.

Seventy-insects were mentioned earlier by Dr. Harris that could be tested for leafy-spurge control. What testing procedures are available for "high-priority" agents? One genus of flea beetles, *Aphthona* spp., are very abundant in Europe that are specific to *Euphorbia* spp. Mr. Eric Maw is presently screening a couple of species of these.

Dr. Harris in his formal presentation made the point that the screening of potential insects for the biological control of leafy spurge would at the same time serve also to assist in delineating the systematic of the host plant. The question was asked, "Where might such work best be done?'' Dr. Harris responded that same of this could be done abroad in either the C.I.B.C. laboratory in Switzerland or in the U.S.D.A. laboratory in Rome, or at Regina or Albany where screening is being done in North America. These would make excellent projects for M.S. or Ph.D. research theses.

Will foliage feeders be any good for controlling leafy spurge? Dr. Harris responded that all types of insect plant feeders must be examined-foliage feeders, seed feeders, girdlers, borers, gall-formers, etc. The screening of *Oberea* is nearly completed now. It kills the stem of spurge by boring, without having to consume it. Numbers of stems declined 65-75% the next year due to *Oberea* in Europe.

Do nematodes have any promise? A nematode looks very promising on Russian knapweed.

It is difficult to find good stands of leafy spurge in Europe. This is an obstacle when searching for insect agents. Mr. Eric Maw worked in Europe last summer and found spurge to be sparse. A good stand there consists of various plants scattered over 10 acres. Most sites are railroad banks and gravel pits. It is not necessary to chemically treat for leafy spurge In Europe because the native insects keep it under control.

What work has been done in using fire to control leafy spurge? Dr. Harris responded that one of his research sites was accidentally burned (which didn't do much to aid their research) and all that the fire did to the spurge was to burn off the tops. The roots were unaffected. Fire will destroy the seed crops, however.

How much work has been done on sheep-cattle relations on leafy spurge inasmuch as sheep often prefer forbs? Can sheep be used to feed where cattle won't? No consensus was reached on this point.

Can a combination of insect and plant pathogen be used? The example of control of prickly pear cactus (*Opuntia* sp.) was mentioned as having resulted from such a combination and it was suggested that such possibilities should be investigated for leafy spurge. Industry will be interested in such controls only if they can realize a profit.

What happens to a biological control when a chemical control is super imposed on it? Because the insect life cycle is fixed, it is the chemical control time of application that has to be varied.

Many insects complement one another in their control, but are there any documented cases of competition between two different insect species for weed control? Dr. Harris responded that two gall flies on knapweed have partial competition, but that the two species together do more damage in controlling the weed than either one species alone.

Do plant galls really affect the growth of plants? Cecidomyiid galls prevent heads from forming and this may cause some control. Gall formation can reduce viability of the seeds produced. *Rhinocyllus conicus* in musk thistle acts something like a gall former. It uses some of the energy that the plant would have otherwise used for seed production.

Mrs. Carie Day of Missoula, Montana, an interested lay-person, reported that she has been involved in attempting to stimulate further funding for the U.S.D.A. Biological Control of Weeds Laboratory at Albany, California. She felt that general public opinion is against agricultural research with consequent general apathy. She urged a new "grass-roots" effort to reverse this. She reported that Montana just passed a house-joint resolution in support of leafy spurge work.

Others in attendance mentioned several agencies already involved with leafy spurge control or research efforts. Examples: a NC (North Central) Experiment Station Project, the Old West Regional Commission, an Interregional Project, and the U.S. Forest Service. The Old West Regional Commission has already proposed a resolution in which they suggest that leafy spurge research should be coordinated through the auspices of the Great Plains Agricultural Council.

Conclusions:

1. The workshop concluded with the consensus that an Action Committee is needed to coordinate research efforts and keep activities going on leafy spurge work so that stagnation does not occur. IT WAS STRONGLY RECOMMENDED THAT EFFORTS BE MADE TO ESTABLISH AND COORDINATE ALL SCIENTIFIC RESEARCH ON LEAFY SPURGE FOR ALL INVOLVED AGENCIES. THIS SHOULD ALSO INVOLVE THE CANADIANS.

2. In no way can biological control work proceed in North America until additional organisms are screened for release. This can be accomplished by supporting staff persons (graduate students) to do screening in the laboratory in Switzerland, Rome, Regina or Albany.

Workshop session: Cultural (mechanical) control of leafy spurge

Dr. Harold Goetz and Dr. William Barker-Moderators

Generally, leafy spurge is not a problem on cultivated land where there are repeated tillage operations. The leafy spurge problem is one of mainly rangelands and disturbed areas.

There needs to be research done involving:

1. Grazing management systems using different kinds of livestock
2. Fire
3. Fertilization
4. Root plowing
5. Mowing
6. Combinations of the above

Probably all of the above will be more effective if coupled with chemical control.

No tillage farming might be plagued with the presence and tremendous growth of leafy spurge. We need research in order to be prepared for this.

The root (rhizome?) buds seem to be a major reason why the spurge plant is so successful. There needs to be physiological research to determine what activates these buds and how these buds could be activated to make the plant vulnerable to some control treatment.

There must be an educational effort to get people to recognize the weed and get them to realize that they must kill it if at all possible.

There needs to be research in the timing of treatments and applications of chemical and the translocation of the chemical.

There is already chemical means to hold spurge populations in check until better control methods are found. Action is needed now if we ever hope to manage the leafy spurge.

Chemical control of leafy spurge workshop session

Chairman: C.G. Messersmith

1. What research should be done?

   A) Why herbicides are ineffective for eradication leafy spurge?

      1. Effect of stage of growth and phenology of plant
      2. Depth of root kill (plant recovery)
      3. Genetic variability of leafy spurge

   B) New application techniques for control of leafy spurge

      1. Roller applicator
      2. Wick applicator

   C) Effect of Herbicide formulations on control of leafy spurge

      1. Pellets vs. liquid for leafy spurge control in a woody ecology
      2. Influence of concentration and carrier on effectiveness, especially for aerial application

   D) Grassland management and chemical control of leafy spurge

      1. Effect of fertilizer on leafy spurge control with herbicides
      2. Effect of grazing on leafy spurge control with herbicides
      3. Effect of burning on leafy spurge control with herbicides
      4. Need for repeated herbicides applications after initial leafy spurge control treatments

   E) Enhancement of herbicide activity on leafy spurge

      1. Growth regulators
      2. Additives
      3. Herbicide combinations

   F) Evaluation of new herbicides developed by chemical companies on leafy spurge

2) Who should do the research on leafy spurge control?

   A) Universities, chemical companies and land management units will be conducting research.

   B) “Permanent” leafy spurge task force should be established - task force may establish subcommittees dealing with research, extension political entities, etc.

3) How do you relate your work to what others are doing?

    A) Research scientists exchange information through established professional societies.

    B) Annual leafy spurge conference - probably at locations of current leafy spurge projects, conference will include formal reports, planning sessions, and field tours.

    C) Intensified extension education programs.

Reprinted with permission from: Proceedings: Leafy Spurge Symposium. Bismarck, North Dakota. June 26-27, 1979. p. 79.

Sponsored by: North Dakota State University Cooperative Extension Service, North Dakota State University Agricultural Experiment Station, Agricultural Research-USDA-SEA, and United States Forest Service.

(Editor's note: The following untitled article appeared at the end of the symposium proceedings. The author's name was not given.)

The help of the Old West Regional Commission could be very effective in the "organizational" and "educational" aspects, as described at the Workshop on June 27. Once direction is set, I'm sure other groups will be willing to help.

I suggest that a well-written Executive Summary be part of the Workshop Report. Properly prepared, this can be of tremendous help to legislators in gathering support for dollars to assist public and private land owners and managers in meeting the costs of control.

During a recent assignment to Washington, D.C., I was exposed to a joint U.S.-Mexico project aimed at reducing desertification of rangelands in southwest United States and northern Mexico. President Carter visited Mexico to garner support for this antidesertification program. I am convinced that the relative productiveness of rangelands of northern United States and southern Canada are much greater than those in the "Antidesertification" zone, and that leafy spurge is an equal or greater threat than desertification. Therefore, I believe we need to pr omote a joint U.S.-Canadian effort on an international scale equal to or greater than that between U.S. and Mexico.

I am currently serving on an interagency Task Force established by Assistant Secretary Rupert M. Cutler to establish goals and policy of the Department of Agriculture as they relate to rangelands as a natural resource. Part of this exercise is to establish the role and mission of each agency in addressing rangelands. I am also involved in the SEA-AR Range Research Planning Project. Leafy spurge is included in the draft copies of both of these reports.

If each of us injects leafy spurge control into the discussion–oral or written–whenever the opportunity arises, I believe we can sell our case.