ELEMENT STEWARDSHIP ABSTRACT
for

Euphorbia esula

Leafy Spurge

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The Nature Conservancy
Element Stewardship Abstract
For Euphorbia esula

I. IDENTIFIERS

Common Name: LEAFY SPURGE Global Rank: G5

General Description:
Euphorbia esula is a perennial plant ranging in size from 6 to 36 inches in height.

II. STEWARDSHIP SUMMARY

Monitoring of areas with known or potential Euphoria esula infestations is critical; adequate control is possible if management procedures are implemented in the early stages of infestation. 100% eradication of spurge is rarely achieved, but infestations can be reduced to manageable levels with the use of herbicides. Picloram is the most effective, and 2 lb/acre applied in the spring and again in fall will provide 85-90% control for several years. A less expensive and also very effective method is to mix picloram at .25 lb/acre with 2,4-D at 1 lb/acre. This mixture applied once a year in the spring will give 90-95% control after about five years.

Whatever the treatment, it is important to realize that spurge cannot be controlled with a single herbicide treatment. Continuous surveillance and reapplication of the herbicide as shoot control decreases must continue for at least 10 years, and probably a good deal longer. For example, management at Devil's Tower National Monument has been spraying on an annual basis for about 20 years and has significantly reduced but not eradicated spurge populations.

Prescribed burning in conjunction with herbicide application can provide excellent control of leafy spurge in open areas. Results are apparently very good whether burning is followed by spraying or vice versa, but as with other methods, repeated treatments are necessary over at least a 5-10 year period.

Control of spurge in wooded or riparian zones can be extremely difficult since picloram is not labelled for use in these areas. Glyphosate and 2,4-D are commonly employed under trees with mixed results.

Biological control is being actively researched at many locations and since the 1960's several insects have been released in certain locations, most notably the spurge hawkmoth, Hyles euphorbiae. Biocontrol agents alone have not so far been effective in controlling spurge populations, but may become valuable if several different insects can be successfully used together or in conjunction with other control methods. Research should

focus on a highly integrated approach to spurge management, with the goal of reducing the amount of herbicides needed for adequate control.

III. NATURAL HISTORY

Range:

Euphorbia esula and its closely related taxa are native to central and eastern Europe with extensions into western Europe and temperate Asia. It is now found worldwide with the exception of Australia. It was most likely introduced into North America via Minnesota with shiploads of oats (Batho 1932).

Euphorbia esula is presently a major economic concern in the northwestern and north-central states of the United States and in the adjacent prairie regions of the provinces of Canada. States with the greatest infestations include Colorado, Idaho, Minnesota, Montana, Nebraska, North Dakota, Oregon, South Dakota, Wisconsin, and Wyoming.

Habitat:

Euphorbia esula occurs primarily in untilled, non-cropland habitats, which include disturbed and undisturbed sites such as abandoned cropland, pastures, rangelands, woodlands, prairies, roadsides, and wastelands. It is tolerant of a wide range of habitats and may occur in rich damp soils such as on the banks of streams or on extremely nutrient poor, dry soils typified by the rangelands of the west. It is most aggressive in semi-arid situations where competition from associated species is less intense. For this reason, infestations generally occur and spread rapidly on dry hillsides, dry prairies, or rangelands. The plants tend to occur on all soils but tend to grow most rapidly in coarse- textured soils (Selleck et al. 1962).

Ecology:

Phenology: Euphorbia esula is one of the first plants to emerge in the spring. It emerges in early April in North Dakota, during March in Iowa and Wisconsin, and late April in Saskatchewan (Hanson and Rudd 1933, Bakke 1936, Selleck et al. 1962). Stem elongation is very rapid as daily temperatures increase from May through June. Seedlings may emerge when temperatures are near freezing (Biesboer, personal observation). Seedlings appear deep red or purplish because of anothcyanin production in the hypocotyl. As the growing season progresses some seedlings will appear to dry up and die but their underground parts will persist and produce adventitious buds especially near the hypocotylar end of the shoot (Raju 1975). The main seedling shoot usually does not survive and flower because of the rapid development of adventitious organs. It is replaced by an adventitious shoot that will mature into the flowering shoot.

Infloresences form on the main axis from May to the end of July with flowering and seed development again occurring for a short time in the fall, usually from axillary branches. Seed development and maturation continue for 4-6 weeks after the appearance of the last flowers with seed dispersal occurring into early August. The plant usually ceases to grow during the hottest and driest weeks of July and August. Stems from seedling or root buds

generally do not flower the first year. During senescence in the fall, the plants turn a pleasant golden-yellow or reddish-yellow before the leaves fall from the plant. The naked stem axis is woody enough to persist from summer to summer and remnants of it can be seen at the base of newly emerged shoot. As light becomes limiting, plants fail to flower, decrease in density, and increase in height. As patches develop, density reaches over 200 shoots/sq m in light soils, and up to 2000/sq m in heavy soils. On heavy soils about 60% of the shoots are produced from seed, whereas on light soils density is maintained and increased mainly by vegetative reproduction (Selleck 1958).

Maintenance: Leafy spurge, once established, will spread very rapidly, crowding out and shading desireable species. It emerges earlier in spring than most other species and also shows allelopathy toward associated species as evidenced by bare ground and lack of other forbs in dense patches of leafy spurge (Steenhagen and Zindahl 1979).

Pests: Although many pests of leafy spurge have been identified, none has been shown to effect much control on this weedy species (Harris et al. 1985).

Reproduction:
Reproduction/Sexual: Flowers of leafy spurge are insect pollinated. The flowers produce copious amounts of pollen and nectar. A survey in Saskatchewan showed 8 orders, 39 families, and 60 species of insects on the flowers of leafy spurge (Best et al. 1980).

Fruits ripen and seeds are dispersed from mid- to late-July in the United States. The number of seeds produced per stalk varies from 252 seeds in habitats where spurge competes with native grasses to ca. 200 seeds where spurge competes with annual weeds and crested wheatgrass (Selleck et al. 1962). Seed yield can be very high. In Saskatchewan, leafy spurge patches were calculated to produce 24 to 3400 lbs of seed per acre (Selleck et al. 1962).

Seeds of leafy spurge have a rather high germination rate of 60-80% (Bakke 1936, Bowes and Thomas 1978, Hanson and Rudd 1933). Seed may remain dormant for ca. 5 to 8 years following maturity, but 99% of the germination occurs within the first two years (Selleck 1958). The optimal temperature for germination is 30-32 C. Alternate freezing and thawing, wet and dry periods, and prolonged dark periods promote germination; scarification does not (Selleck 1958). The peak period for germination is late May to early June, but given adequate moisture seeds will germinate throughout the growing season.

Seed dispersal is initially affected by explosive dehiscence of the seed capsule. The seed may be ejected up to 4.6 m from the parent and distributed fairly uniformly from 0.3 to 4.0 m from the plant (Hanson and Rudd 1933). The seeds can also float and initial infestations often occur along stream or river banks where seeds have floated into appropriate habitat (Biesboer, personal observation). Birds have been implicated in spreading seed but documentation is limited except for sharptail grouse (Noble 1980).

Reproduction/Asexual: One of the most important aspects of leafy spurge biology (in addition to production of large amounts of seed) is its ability to reproduce and spread rapidly via vegetative reproduction. Vegetative reproduction occurs from both crown buds and root buds that overwinter and produce new shoots in the spring. The crown of leafy spurge develops just under the surface of the soil and produces a large number of buds that annually produce new stems. The crown region of the plant can also produce new roots that contribute to the spread and persistence of the plant. Leafy spurge crowns can live for many years but the number of years is unknown (Bowes and Thomas 1978).

Seedlings have a remarkable capacity for vegetative reproduction, and can develop buds within 7-10 days after emergence. Buds will form on the proximal portion of the hypocotyl of the seedling. The number of buds produced on the hypocotyl is limited, unlike the roots where up to six times as many buds will form. Bud formation will limit the growth of the seedling. All hypocotylar buds and root buds have the potential to produce a new shoot axis.

Once control practices have been initiated, it is the root system that ensures that leafy spurge spreads and persists in the soil. The root system, consisting of long roots and short roots, can give rise to shoot buds almost anywhere along its length. The long shoots give rise to most of the buds and have been excavated to a depth of 4.8 m (Best et al. 1980). The upper portion of the plant can be killed by herbicides or tillage but living roots below the treatment zone or detached roots will regenerate new shoots. Cultivation or other shallow removal of leafy spurge plants can actually cause a net increase in the number of stems in an infestation. This was demonstrated by Selleck et al., (1962) who showed that regrowth of leafy spurge after rototilling averaged 316 shoots/sq m in comparison to 134 shoots/sq m in undisturbed control. Shoots can emerge from 90 cm of overlying soil for 5 successive years after removal of the major portion of the root system by excavation (Coupland et al. 1955).

Impacts:
Euphorbia esula presents a management problem because it is a long-lived, aggressive perennial weed that tends to displace all other vegetation in pasture, rangeland, and native habitats. It is invasive because of the large number of seeds it produces and because it has the capability of producing large numbers of underground shoot buds that can each produce a new shoot. It is particularly aggressive in drier sites such as hillsides and prairies. Yield reductions of desireable forage species associated with stands of leafy spurge have been reported to decrease from 10 to 100% (Reilly and Kaufman 1979). Forbs and grasses in natural areas may be completely displaced by leafy spurge in a few years if the infestation is left unchecked.

Euphorbia esula is rapidly spreading into many areas of the midwestern United States. Control is very difficult and must begin before successful establishment or control may become impossible. Rapid re-establishment of dense stands will occur after an apparently successful management effort because of the long-lived root system present in the soil.

Approximately 2.5 million acres are infested with leafy spurge in the U.S. and Canada with the number of infested acres increasing yearly (Dunn 1979). It must be pointed out that the weed can spread very rapidly as evidenced by the doubling of the acreage infested by leafy spurge in North Dakota from 1973 to 1982, a period of 9 years. The Minnesota Department of Transportation estimates that 800,000 acres of land in 80 counties in Minnesota have leafy spurge on it with the most severe infestations occurring in counties bordering North Dakota (Holm pers. comm., Minnesota Dept. of Transportation, 1985).

IV. CONDITION

V. MANAGEMENT/MONITORING

Management Requirements:

Euphorbia esula is an extremely aggressive and persistent weed that is rapidly spreading into many areas of the midwestern United States. It is invasive because of the large number of seeds it produces and because it has the capability of producing large numbers of underground shoot buds that can each produce a new shoot. If left unchecked, natural areas may become completely overrun with leafy spurge in the period of a few years. It is particularly aggressive in drier sites such as hillsides and prairies. Control is very difficult and must begin before successful establishment or control may become impossible. Rapid re-establishment of dense stands will occur after an apparently successful management effort because of the long-lived root system present in the soil.

Chemical Control: Chemical control, except for continuous tillage or grazing in agricultural situations, is the best method for elimination of leafy spurge. Many herbicides have been used to control leafy spurge with varying degrees of success (Lym and Messersmith 1983). These include picloram, 2,4-D, dicamba, glyphosate, and others. At the leafy spurge symposium at Montana State University in 1985 it was shown that picloram was the most effective in controlling spurge. Because picloram is expensive, the less costly herbicide 2,4-D is sometimes used alone or mixed with picloram on large areas of spurge infestation. Biannual application of 2,4-D alone would likely only prevent seed production and spread of spurge with little change in area of original infestation (Lym and Messersmith 1987). Messersmith (1987) reported that low rates of picloram with 2,4-D in repeated treatments gave the best long-term control of spurge. Although 2,4-D used alone does not offer as effective control as picloram, it may be preferred in some cases due to its lower cost and perceived lower health risk (Welles pers. comm., MRO, 1987). A recent study has shown that 2,4-D when used as a set-up treatment for picloram has virtually no effect on control of spurge (Gamal 1986). Dicamba and 2,4-D are often used as follow up treatments to picloram but with mixed and often disappointing results (Bybee 1981, Mitich 1972).

Dicamba has met with some success in the control of spurge, but is costly and breaks down quickly in the soil. Picloram is clearly more effective than dicamba in the eastern portion of spurge country (North and South Dakota, Nebraska, Minnesota, and

Wisconsin) due to its longer soil residual activity. However, in western states, such as Wyoming, Montana, and Colorado, where rainfall is relatively low, dicamba is not leached or broken down as quickly and has been found to give quite effective control (Wrage pers. comm., MRO, 1987). In these states, dicamba may be preferred because of its short soil residual time and corresponding decreased threat to returning desired forbs. Dicamba at high rates (6-8 lbs/acre) may decrease production of native grasses. The bluegrasses (Poa spp.) are the most tolerant grasses to dicamba at high rates (Lacey et al. 1985). Picloram at high rates will also damage grasses, but it is usually prescribed at relatively low rates for spurge control.

Generally leafy spurge control with herbicides increases native grass production, although picloram can damage smooth brome, and glyphosate applied in the fall severely decreases forage yield (Gylling and Arnold 1985). Picloram and dicamba are restricted from use among trees and 2,4-D amine or glyphosate are recommended. Care must be taken to avoid contacting tree foliage with herbicide directly or from spray drift.

Two other chemicals that show promise in spurge control and which may be available in the future are flouroxypyr (Whitson pers. comm., MRO, 1987) and sulfomenturon (Messersmith pers. comm., MRO, 1987).

Leafy spurge is sensitive to the timing of herbicide application, with control being most effective with 2,4-D, picloram or dicamba in mid-late June (seed development) and in late September (fall regrowth) (Lym and Messersmith 1983). Distinction between appearance of bracts and true flowering is important for timing herbicide application. Spring herbicide application is more effective on plants with developing true flowers than on plants with developed bracts but undeveloped flowers (Eberlein et al. 1982). Glyphosate is most effective when applied after seed set in mid-summer or in late September after fall regrowth has started, but before a killing frost (Lacey et al. 1985). Chemical control must be thorough and persist for several, often many, years. Some herbicides must be applied annually or semi-annually. One application of picloram will sometimes provide adequate control for several years but follow-up applications will be necessary when percent control drops. Smith (pers. comm., Lostwood National Wildlife Refuge, Maryland, 1987) emphasized the importance of two applicatons in one season, once in spring to prevent seed development and again in fall to promote translocation of the herbicide to the roots. If infestations are limited and caught early, 100% eradication may be possible. If infestations are severe, it maybe difficult to stop the spread of spurge except at great economic and biological expense.

The following are some of the most widely used or recommended herbicides and application rates:

Picloram: Scattered patches or nearly inaccessible areas of spurge: 2 lbs/acre late spring picloram followed by 2 lbs/acre early fall; the result is 85-90% shoot control for 3-4 years; when shoot control drops below 75% retreat with 0.5 lb/acre. As long as the area is under

continuous surveillance, Messersmith (pers. comm., MRO, 1987) suggested using 1 lb/acre initially for less damage to grasses.

Large uniform infestations that are accessible and easily treatable on a yearly basis: late spring, 0.5 lb/acre picloram; 70% control; must be followed by 0.5 lb/acre once/year.

(Picloram is marketed as TORDON, and in the past has been available in pellet form (Tordon 2K and Tordon 10K) and in liquid form (Tordon 22K, Tordon K, and Tordon 101). The pellet forms are no longer available. Tordon 22K is labelled for range and pasture and consists of picloram at 2 lb/gal. Tordon K is labelled for utility rights of way and forestry and wildlife habitat, but is essentially the same product as Tordon 22K. Tordon 101 is a mixture of picloram and 2,4-D at .54 + 2 lb/gal (Brooks 1987).

Picloram + 2,4-D: A less expensive and very effective treatment is 0.25 lb/acre picloram mixed with 1 lb/acre 2,4-D, applied once a year in the spring. This will provide 40-60% control the first year, and if reapplied on an annual basis will add about 10% control each year until over 90% control is achieved after 4-5 years (Messersmith 1987, Lorenz 1987).

2,4-D: Another inexpensive treatment, but less effective than picloram: 2,4-D low volatile ester, oil- or water-soluble amine formulations applied annually at 1.5 lb/acre twice a year in mid- June and early to mid-September, or 3 lb/acre applied once per year in spring or fall.

Among trees use 2,4-D oil- or water-soluble amine at 1.0-1.5 lb/acre applied annually in spring or fall.

Glyphosate: Another treatment that may be used among trees is glyphosate at 0.75 lb/acre, applied from mid-August to mid- September; 80-90% control, may require follow up the next spring with 2,4-D at 0.5-1.0 lb/acre (Lacey et al. 1985).

Dicamba: Dicamba at 4-8 lbs/acre applied in mid- to late-June will provide 50-80% control the first year, but control usually decreases the second year due to the low residual effectiveness of the herbicide. As mentioned above, dicamba may be more effective in low rainfall areas of the western U.S.

Dicamba + 2,4-D at .5 + 1 lb/acre may provide better control than either chemical alone (Gylling and Arnold 1985).

Biological Control: There are high hopes for the use of biological control agents in the control of leafy spurge, although none of the insects tested have become well established in the U.S. Research is ongoing at a number of locations on at least 15 insects as possible biocontrol agents for spurge (see Research Programs). The most well-known and widely studied of these to date has been the spurge hawkmoth (Hyles euphorbiae). The moth is native to southern and central Europe, northern India and central Asia, and was first introduced in North America in Canada in 1963 (Holloway 1964). Several days after the

adult female deposits eggs on leafy spurge plants, small larvae emerge and begin to consume spurge foliage as they proceed through five instars over 2-3 weeks. After the fifth instar the larva burrows into the soil and pupates (Forwood and McCarty 1980). H. euphorbiae has been released at a number of sites in Montana, North Dakota and some neighboring states on an almost annual basis since 1964, but the moth does not overwinter well and has not become established at many sites. Lacey et al. (1985) reported good establishment of the hawkmoth at two locations in Montana. According to Lorenz (pers. comm. 1987) once colonies build to a certain population density they become susceptible to a virus that causes severe mortality, so it is difficult to maintain moth populations at densities sufficient for control of the spurge. Since spurge is also very resistant to defoliation, the hawkmoth by itself is not a promising biocontrol agent. It has been suggested, however, that adequate control of leafy spurge will require a combination of several insect control agents that attack different parts of the plant, most likely in conjunction with the use of herbicides or other control methods, and the hawkmoth may be valuable as one of these agents (Lorenz pers. comm. 1987, Forwood and McCarty 1980).

Research on other agents is still in screening or early stages of release programs and results will not be clear for several years. Some of the more promising agents for control of spurge are: stem and root borers, such as the cerambycid Oberea erythrocephala, and the clear-winged moth Chamaesphecia tenthrediniformis; the gall midge Bayeria capitigena, which prevents flowering of spurge; and the rust fungus Uromyces scutellatus, which devastates shoots by causing systemic infections (Lacey et al. 1984, Schroeder 1980, Pemberton 1986, Bruckart 1986).

Other control methods: Fire would not be likely to provide adequate control of spurge if used alone because its effect would be on top growth and seeds, and established plants would quickly resprout. However, there have been some reports indicating that fire used in conjunction with herbicides gives better control than herbicide application alone (Messersmith pers. comm. 1987, Bjugstad pers. comm., South Dakota School of Mines, 1987, Plumb pers. comm., Ordway Prairie, South Dakota, 1987, Smith 1987). Plumb (1987) suggested that burning in early May followed by herbicide application in June (just before seed set) might offer adequate control.

Bjugstad (1987) conducted burning and herbicide application tests on leafy spurge in South Dakota in 1984-85 with very good results. Plots were sprayed with a mix of 2,4-D and picloram in September 1984 and burned the following April, sprayed again in June and burned again in October of 1985. Bjugstad (1987) stated that leafy spurge generally burns very well due to its high oil content, but he felt that a herbicide application before burning allowed for an even better fire. Burning reduced seed viability to about 10%, and seedling development was greatly reduced in the burned and sprayed plots compared to plots that received either burning or herbicide treatment alone. Plots were located on a floodplain dominated by leafy spurge and silver sage brush (previously existing grasses having been replaced by the spurge), and in upland areas dominated by spurge with grasses such as needle and thread (Stipa comata) and western wheatgrass (Agropyron smithii). Two years

after treatment, the burned and sprayed plots were still "islands" virtually free from spurge within a larger spurge-infested area, and many of the native grasses and forbs had become reestablished.

Bjugstad (1987) stated that spurge generally presents a problem for chemical control because of its indeterminate growth. Herbicides are developed to be most effective during stages of greatest vegetative growth and in a single stand of spurge at one time some plants may be releasing seed, some in full bloom, and some not yet flowering. The burning treatment alone greatly stimulated vegetative production, and those plots produced a thick, uniform stand of spurge which appeared ideal for application of herbicides. Thus, burning first followed by herbicide application may also be very effective for spurge control, although this was not tested (Bjugstad 1987).

Smith (1987) reported using prescribed burning to remove litter and seeds followed by herbicide application on the Lostwood National Wildlife Refuge in North Dakota. The burning either burns up the seeds or scarifies them causing germination. With the litter removed the newly sprouted seedlings are easily detected and then sprayed with herbicide. The timing of the burn does not seem critical, except that it should be 3-4 weeks before herbicide application. At Lostwood, burns are conducted primarily for control of woody species and may be set in mid-June or late summer. Burning must be conducted repeatedly (for example every other year for 5-6 years) to ensure that all seeds are burned or germinated, and herbicide should be applied twice a year, in the spring and fall. Smith (1987) reported excellent control of spurge with this method.

Repeated mowing or hand cutting may also be used to control seed production, but must be used in conjunction with herbicides for adequate control of stand expansion. Repeated mowing or cutting during a single season is necessary because a single cutting (removal of apical meristem) will stimulate the development of inflourescences on lateral branches (Selleck et al. 1962). Mowing will also affect grasses and forbs in the mowed area. Since leafy spurge resprouts rapidly, mowing would probably reduce the competitive ability of other species. Selective clipping of the spurge may be preferrable but is also time-consuming. For small patches, the use of a hand sicle allows relatively rapid cutting of spurge with little adverse effect on other plants. An automatic "weed eater" works more quickly but allows for less selectivity than a hand sicle (Plumb 1987). Clipping the tops to within 4 inches of the ground just before seed set will prevent the plants from going to seed. If no herbicide is applied clipping may be necessary again in mid summer to prevent further seed development. Without a fall herbicide application, this method may inhibit stand expansion but is unlikely to reduce spurge abundance in a patch.

Grazing of sheep has been used successfully to control spurge on ranches in Montana, but ranchers agree that once the sheep were removed the spurge would quickly return (Lacey et al. 1984).

Competition from other plant species may be a means of control in natural areas, but few, if any, plants have been found that show early spring growth, have dense foliage, and are

resistant to broadleaf herbicides. The University of Wyoming is conducting interseeding tests with spurge and ten grass species on tilled and untilled areas in conjunction with herbicide treatment. Preliminary results show that some grasses performed better on tilled and some on untilled areas, but results must be monitored for several years before any conclusions are reached (Whitson pers. comm., Univ. Wyoming, 1987). In Colorado, leafy spurge appears to be limited to low altitude, mesic, mainly riparian habitats. Managers are looking at the effects of allowing the shrubs in riparian zones to encroach and compete with the spurge, instead of eradicating spurge and shrubs alike with herbicides (Galatowitch pers. comm., Colorado Natural Areas Program 1987).

Nature Conservancy Preserves.
North Dakota: Cross Ranch currently has about two dozen small localized patches of leafy spurge totalling approximately three acres. Management consists of spraying picloram each year in June in open areas (old fields, prairies, railroad edges) at 2 oz/gal, and glyphosate in forested areas each year in August or September at 4 oz/gal. Infestations are not severe but each year new patches are discovered and the management goal is to eliminate them before they spread. Contact: Bob Hamilton, Cross Ranch, Hensler, ND 58547. 701-794-8741.

South Dakota: Ordway Prairie began to see leafy spurge in 1980 and for several years it was simply hand chopped. It began to spread so picloram was applied in pellet form in the spring of 1985 and again in liquid form in the spring of 1986. In 1987 there were just scattered patches, which management is continuing to chop by hand. Abundance of flowering stems is down by 80% since 1985. If necessary 2,4-D will be applied in 1988 or 1989 as a follow-up treatment. Contact: Glenn Plumb, Ordway Prairie, Star Route 1, Box 16, Leola, SD 57456. 605-439-3475.

Altamont Prairie was acquired in 1963 and no active management was employed for the next seven years. Leafy spurge was already becoming a severe problem in 1970, the first year of active spurge control. 2,4-D was sprayed in the spring of 1970 and again in 1972 and then every year since 1977. In 1974 and 1976, spurge hawkmoths (Hyles euphorbiae) were released, but did not become established. Beginning in 1982 picloram has been sprayed every year on the areas of heaviest spurge infestations. Burns were conducted in late May of 1984, 1985, and 1986. Spurge continues to be a severe problem at Altamont.

Crystal Springs is a new Nature Conservancy acquisition in South Dakota at which there are patches of leafy spurge. Monitoring and mapping of patches is being conducted in 1987 and control methods, probably application of picloram, will subsequently be implemented.

Nebraska: At Niobrara Valley Preserve, five to six acres of grassland and several hundred acres of woodlands have areas of spurge infestations. In 1986 all the non-forest sites were treated with picloram 2K pellets and picloram liquid will be reapplied in two to three years when shoot control is expected to decline. No control measures have been implemented in the wooded lands and it is expected to be very difficult to combat the spurge in these

areas. Contact: Al Steuter, Niobrara Valley Preserve, Rt. 1, Box 358, Johnstown, NE 69214. 402-722-4440.

Iowa: The largest area of spurge infestation on Nature Conservancy land is on the Sioux City Preserve. Management applied picloram liquid by hand (herbicide dripped directly onto individual stems) to open area infestations in the spring of 1986 and 1987. An experimental mowing treatment is planned for one large patch in a disturbed area. The entire area will be mowed every few weeks over two seasons, and herbicide (picloram) will be applied the third season. Management is also planning a burning treatment in conjunction with the herbicide in the other grassland areas. Hillsides, which have small patches of spurge, will be burned in the fall and followed with picloram spot application in the spring. Lowland areas, where spurge infestations are the greatest, will be burned in the spring and also followed with picloram application. The largest infestations, as at Niobrara Valley, are in wooded areas where no control measures have been implemented. Contact: Ethen Perkins, TNC Iowa Field Office, 424 10th St., Suite 311, Des Moines, IA 50309. 515-244-5044.

Minnesota: Minnesota's biggest spurge problem is at Bluestem Prairie in the northwestern corner of the state. In 1984 four patches were known. Intensive searching revealed 50 patches by the end of 1985, 104 patches in 1986, and over 177 patches by 1987. Many small patches have grown together since 1985. Data collected on 10 individual patches showed about 129% increase in patch size over two years. Management is applying picloram to the most severe infestations, and many areas were burned or mowed in addition to the herbicide application. Spurge is also a management concern on several other Minnesota preserves. Contact: Rick Johnson, TNC MN Field Office, 1313 5th St. SE, Minneapolis, MN 55414. 612-379-2134. Non-Nature Conservancy Lands.

This is by no means a complete list of areas currently under management for control of leafy spurge. The information and contacts are included because they are examples of successful and/or informative treatment programs.

Devils's Tower National Monument in Wyoming has been applying herbicides to spurge-infested areas for about 20 years. Years ago there were large infested patches over the entire 14,000 acre park and spraying was conducted by truck on a relatively large scale. 2,4-D was used initially until it was discovered that picloram was more effective. There are no longer large patches of spurge so picloram (22K liquid at 1 gal/acre) is spot sprayed on individual plants by an employee who walks the ground with a backpack sprayer throughout the season. These procedures have successfully reduced the abundance of spurge to scattered patches, but herbicide treatment will continue indefinitely to prevent spread and reinfestation. Contact: Bruce Miller, Maintenance Foreman, Devil's Tower National Monument, Devil's Tower, WY 82714. 307-467- 5603.

The Custer National Forest has a total of over 8000 acres of spurge infestations, the major areas being located in the Sheyenne District in North Dakota. Management has been applying picloram annually at .25-1 lb/A. The number of infested acres has not so far

decreased, but spread is being prevented, except in drainage ditches that are restricted from use of picloram. Contact: Mike McNeil, Resource Assistant, Sheyenne National Grassland, Box 946, Lisbon, ND 58054. 701-683-4342.

The Lostwood National Wildlife Refuge in North Dakota has significantly reduced the abundance of leafy spurge with burning plus herbicide application. Burning is prescribed mainly for control of woody species and is conducted in mid-June or late summer every other year (there is not enough fuel to burn every year). Picloram has been sprayed twice a year at recommended rates in mid-June and September since 1979. Herbicide application is always conducted within three to four weeks following a burn, after the surviving seeds have germinated and sprouted shoots. Areas on the refuge that were once spurge infested no longer have spurge. Contact: Karen Smith, Lostwood Refuge Manger, Lostwood National Wildlife Refuge. 701-848-2722.

Roosevelt National Park has a minimum of 700 acres of leafy spurge infestations. Management has been spot spraying picloram since about 1975 and this has been effective at maintaining or decreasing abundance on localized areas, but park-wide, the spurge population has been steadily increasing. The park is scheduled to be an experimental site for release of two biocontrol agents for spurge: the flea beetle Apthona flava and the gall midge, Bayeria capitigena, which will be released in experimental plots in 1987. Contact: Jeff Bradybaugh, Theodore Roosevelt National Park, P.O. Box 7, Medera, ND 58645. 701-623-4466.

Monitoring Requirements:
Monitoring of Euphorbia esula on preserve lands is essential to track the success of control practices. Since the root system is extensive and persistent, new shoots can emerge even after complete eradication of above-ground tissues. Monitoring and repeat control measures are generally considered necessary for at least ten years following initiation of active management.

Monitoring can be accomplished through aerial photography (see below) and ground observation (e.g. during herbicide application). Spurge is most easily detected when in flower from late May to late June. Patches should be carefully surveyed and mapped annually.

Monitoring Programs:
The U.S. Forest Service is currently researching protocol for aerial photography of Euphorbia esula. Studies are being conducted to determine the best scale (1:16,000, 1:24,000, etc.), film type and season in which to conduct aerial surveys, and a user's handbook is in the making. Contact: Dick Myhre, U.S. Forest Service, Forest Pest Management-Methods Application, Fort Collins, CO. 303-224-1785.

Lee Miller at the University of Nebraska is marketing a highly sophisticated image processing and analysis package, which can be used in conjunction with aerial

photography to map spurge infestations, and other important species as well. Contact: Lee Miller, MicroImages Inc., 932 Lakeshore Drive, Lincoln, NE 68529. 402-435-3864.

VI. RESEARCH

Management Research Programs:
Researchers at North Dakota State University are investigating about 15 different insects as potential biocontrol agents for Euphorbia esula. Particularly promising agents include several stem and root borers, a gall midge that stops flowering, and a larva that consumes seeds prior to dispersal. Various herbicides and application rates are also being continuously tested. A new chemical being tested at NDSU that looks promising for control of spurge is sulfomenthuron. The Cooperative Extension Service at NDSU publishes a leafy spurge newsletter 4-5 times a year. Contact:

Russell Lorenz, Editor, Leafy Spurge News, 1924 North Grandview Lane, Bismarck, ND 58501. 701-663-6445.

Calvin Messersmith, Dept. of Agronomy, North Dakota State University, Fargo, ND 58105. 701-237-7971.

Research on biocontrol and herbicide use is also being conducted at South Dakota State University. Contact:

Leon Wrage, Extension Weed Specialist, Plant Science Dept., South Dakota State University, Brookings, SD 57007. 605-688-5121.

At the University of Wyoming, research is being carried out on chemical control, interseeding of spurge with grasses, mowing and biocontrol. A new chemical that has been found to be very effective in controlling spurge and that shows excellent grass tolerance is flouroxypyr. Interseeding studies are showing that some grasses may be good competitors against spurge when used in conjunction with herbicides (such as flouroxypyr). Contact:

Tom Whitson, Extension Specialist - Weed Science, P.O. Box 3354, University Station, Laramie, WY 82071. 307-766-3115.

Jeff Littlefield, Dept. of Entomology, P.O. Box 3354, University Station, Laramie, WY 82071. 307-766-5199.

Research at the University of Minnesota is focused on spurge development and allelopathic inhibition of seed germination. Contact:

David Biesboer, Dept. of Botany, 220 BioScience Center, U of MN, St. Paul, MN 55108. 612-376-1558.

In Montana, Research has been ongoing for a number of years. Current projects include grazing of spurge with sheep and goats and biological control. Contact:

Peter Fay, Dept. of Plant and Soil Science, Montana State University, Bozeman, MT 59717. 406-994-5061.

Norm Rees, Dept. of Entomology, Montana State Univ., Bozeman, MT 59717. 406-994-6405.

Management Research Needs:
Integrated pest management should be a priority research area for Euphorbia esula. It is widely accepted that control of spurge is a complex problem that will require an integrated approach. The use of herbicides has helped reduce spurge abundance and/or prevent its spread in many areas, but the chemicals must be reapplied, often on an annual basis, for an indefinite number of years to maintain control and prevent recurrences. Non-chemical controls would reduce the dependence on biocides and might help in areas where use of picloram, the most effective chemical, is restricted (e.g. in forests and wetlands).

Control of Euphorbia esula in wooded areas is a particular problem at several Nature Conservancy preserves, notably Niobrara Valley in Nebraska and Sioux City in Iowa, and effective management programs are lacking in these areas. The goal of research should be to develop effective control programs for leafy spurge that make use of a variety of methods (i.e., biological control, mowing, burning) and would allow for a gradual reduction in herbicide applications.

More information is also needed on Euphorbia esula biology, particularly in the areas of plant development and ecology. Questions of interest include the following: What are the germination requirements of leafy spurge, and how are seeds dispersed? How does crown bud and root bud development proceed? Would application of any plant growth substance inhibit vegetative reproduction? Can cold hardening of crown buds in the fall be prevented such that the crown would not survive over winter? Can any desirable grasses or broadleaf species be managed to outcompete and displace spurge in certain areas?

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

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