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# The taxonomy and biology of leafy spurge

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## The problem

Leafy spurge (*Euphorbia esula* L.), a polymorphic complex of taxa most likely composed of a single highly variable species, is a weed that has tremendous economic impact in the United States. Leafy spurge currently infests much of the open rangeland of the upper Great Plains, mainly in the prairie states of North Dakota, South Dakota, Montana, Minnesota, Nebraska, Idaho, and Wyoming (Nobel *et al*. 1979). The ever-spreading presence of this weed on highway right-of-ways (Koukkari 1980) and in protected natural areas (Biesboer 1985) of Minnesota is a major problem that is becoming of greater concern each year.

In North Dakota, the cost of leafy spurge to agriculture and other agencies in the state has been well documented (Messersmith and Lym, 1983; Leistritz *et al*. 1991). Leistritz; *et al*. (1991) recently detailed the monetary losses of North Dakota to leafy spurge infestation. Primary loss of seasonal carrying capacity of pastureland and decreased land values for ranchers coupled with secondary effects such as business losses to households, retail trade, agriculture, services, etc. resulted in an estimated loss to the state of $105 million in 1989. Economic losses are detailed for other states mostly in various state publications and reports and also show that their losses run into the millions of dollars as well. Unfortunately, the battle to control leafy spurge is being lost. During a span of nine years (1973-82) the number of acres infested by leafy spurge in North Dakota has doubled (Watson 1985). Today, leafy spurge infestations in the United States may range from 2.5 to 3.0 million acres (estimated by the authors).

The number of acres infested with spurge in Minnesota is difficult to determine because recent weed survey data is not available for the state. Based upon some recent estimations, about 800,000 acres of land have leafy spurge (Leo Holm, Agricultural Engineer, Minnesota Department of Transportation, pers. comm., and University of Minnesota, Herbarium information). Populations of leafy spurge appear to be increasing rapidly in the mid-West. Within Minnesota, leafy spurge infestation has reached a serious, if not critical level.

## Origin and distribution

Except for Australia, leafy spurge is found throughout the world. The species probably originated in a region that includes eastern Europe and western Asia. It can be found as far north as Scandinavia and as far south and west as Italy and Spain. During the 1800's it was documented as a species found in Massachusetts (1827), New York (1876) and Michigan (1881) (Britton 1927) and by 1913 it was found growing in the western prairie regions of Canada and the United States (Dunn 1979).

The mode of introduction of leafy spurge to the United States has been hypothesized by Dunn (1985) to have occurred independently in several ways: 1) as seeds present in the soil of the ballast of cargo ships carrying goods from Europe in the 1700's and 1800's; 2) in the seed stocks of Mennonites that emigrated to the prairie states from Russia in the decade of 1870 to 1880; 3) in smooth bromegrass seed (*Bromis inermis* L.) that seedsmen introduced to Canada and the northern United States from Russia and Hungary forage crop; and 4) probably by Mennonites settling in Minnesota who imported many bushels of oats from Russia that were probably contaminated with leafy spurge seeds (Batho 1931). In any case, leafy spurge has become firmly established in the United States and is still spreading.

## Morphology and evolution

Leafy spurge belongs to a family of dicotyledonous plants called the Euphorbiaceae. The Euphorbiaceae is a large family encompassing morphologically diverse forms of herbs, shrubs and trees comprising approximately 7000 species in 300 genera. The family is distributed throughout the world with the exception of polar regions. The genus *Euphorbia*, a large genus of about 1600 species, is characterized by plants that exude latex when injured and a more or less regular bisexual cyathium. The cyathium is an inflorescence condensed to form what appears to be a single flower. The inflorescence is formed by the compression of internodes, the absence of petals on individual flowers, and the reduction of each staminate flower to a single stamen. A perianth-like arrangement of 5 bracts occurs in most cyathia separated by 4 horn-like bodies that represent the combined stipules of the subtending bracts. In the middle of the cyathium is a solitary pistillate flower with a tricarpellate ovary on a long stalk. The tips of the bracts alternate with 4 or 5 glandular nectaries.

The fruit of many euphorbs is a triple, woody, and capsular schizocarp. Upon ripening, the fruit divides into three sections, each containing a seed, which is explosively dehisced. Earliest reference to the genus *Euphorbia* dates from the period of Hippocrates who was born about 465 B.C. The botanists and physicians of antiquity were interested in the few known species of *Euphorbia* primarily for the purgative value of their latex. The common name of spurge was probably derived from this use of a latex producing plant.

As previously mentioned, a great amount of morphological variation occurs in the genus *Euphorbia.* Many are herbaceous (as typified by *E. esula*), especially species found in the New World, but shrubs and woody plants do occur in the group. Chief interest has

focused on the many unusual succulent species found in the Old World. Many of these forms have converged morphologically to resemble the Cactaceae. As in the cacti, *Euphorbia* illustrates almost spherical forms, ridged axes, cylindrical forms, coralline forms, dwarf and arborescent forms and are often well-armed with thorns.

Studies of the phytochemistry and starch grain morphology of the non-articulated cells found in *Euphorbia.* (Biesboer and Mahlberg 1981) coupled with other data such as basic chromosome number and general morphology suggest that a large herbaceous subgenus of 500 members, the subgenus Esula, is primitive within the genus. In other words, herbaecous species such as *E. esula* have given rise to the many diverse forms present in this complex genus. Evolution has probably occurred along two lines originating in the subgenus Esula, namely an herbaceous line having trinucleate pollen and a basic chromosome number of x=7 and a succulent line having binucleate pollen and a basic chromosome number of x=10.

The name *Euphorbia esula* L. is the name generally used by North American botanists to identify leafy spurge. Its correct name is *Euphorbia podperae* Croiz. (Richardson 1968), but since it is not a name of common usage in North America, the plant will probably always continue to be referred to as esula. It is suggested, based on studies by Dunn and Radcliff-Smith (1980), that most of the individual populations of leafy spurge in the United States are hybrids between *E. esula* and *E. waldsteinii* (Sojak) Radcliffe-Smith (*E. virgata*).

## Phenology and development

We have carefully studied the phenology and development of leafy spurge in Minnesota. Leafy spurge is an herbaceous, deep-rooted perennial weed. Plants ranges in size from about 0.3 m to 1.0 m in height and develop from a usually woody crown located just below the surface of the soil. Each crown can produce from one to more than twenty upright shoots, which contributes to the almost shrub-like appearance of older plants. In Minnesota, we have found stem densities in the range of about 120 to 290 stem s/m$^2$ in many populations. The leaves of the plant are quite variable in length but are generally narrow, lanceolate to ovate, slightly broader beyond the middle of the leaf, sessile and have a characteristic blue-green appearance. In Minnesota, shoots emerge rapidly in late April and thus the species is among the earliest to be seen growing in the spring. In fact, reddish buds or short shoots can be found under the snow in winter. This early development and rapid growth gives leafy spurge a tremendous competitive advantage over other more desirable species. Stem elongation is very rapid as daily temperatures increase from May through June. Stems remain green during summer but become yellowish-red to red during fall senescence. Dead stems are rather persistent and can remain standing for a year or more after senescence.

The specialized inflorescence or flower cluster of leafy spurge is called a cyathium. It is insect pollinated and produces copious amounts of pollen and nectar. Insects belonging to 8 different orders and representing 60 species in 39 families could serve as pollinators of leafy spurge (Best *et al*. 1980).

Seedlings are particular hardy and can emerge from the soil when temperatures, are near freezing. Seedlings are easy to recognize because they are a deep red or purplish in color due to anthocyanin production in the hypocotyl. As the wing season progresses, some seeds will appear to dry up and die but their roots 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 will be replaced by one or more adventitious shoots that will mature into flowering stalks.

All organs of leafy spurge produce a milky white 'sap', called latex, from specialized groups of cells called non-articulated laticifers. If a leafy spurge plant is injured, the latex can be seen to flow readily from injured surfaces. The latex of many euphorbiaceous species contains rubber, alkanes, $C_{28}$ - $C_{30}$ triterpenes and their esters, various polyfunctional polycyclic diterpenes and cryptic irritants starch, and many proteins. Some of these compounds have been isolated from leafy spurge latex but many have not. The latex of leafy spurge has been noted to produce contact dermatitis in susceptible individuals. Cattle will not consume leafy spurge because it causes severe irritation of the mouth and digestive system. It may also cause scours, and occasionally results in death (Selleck *et al*. 1962). However, sheep and goats can be made to accept and graze on spurge and some researchers suggest that these animals may be used as a mean to control leafy spurge (Lacey *et al*. 1984).

Inflorescences (clusters of flowers) are produced on the main axes of the plant during May to the end of July. The flowering process, and subsequent seed development, occur again in the fall, but usually from axillary branches. Seed development and maturation continue for 4-6 weeks following the appearance of the last flowers. The plant usually ceases to grow during the hottest and driest weeks of July and August.

Fruits ripen and seeds are dispersed generally from late June into August and then again for a short span of time during the fall. According to results from a study conducted in Saskatchewan (Selleck *et al*. 1962), mature plants produced about 200 to 252 seeds per plant and the yields ranged from 27 to 3800 kg seed/ha. Highest yields occurred when native grasses were mowed. The effects of mowing relate directly to the excision of stem apices that in turn enhance the development of lateral branches and a subsequent increase in the total number of inflorescences produced on each plant.

Reseeding is initially affected by the explosive dehiscence of the seed capsule. Seed may be ejected up to 4.6 m from the parent plant and be distributed fairly uniformly from 0.3 to 0.4 m from the plant (Hanson and Rudd 1933). Leafy spurge seeds can float and initial infestations of land previously devoid of the species often occurs along stream or river where seeds have floated into a new habitat. The number of seeds that germinated from a given population is relatively high. In the laboratory, we have found that 50 to 80% of the seeds collected from various populations in Minnesota will germinate after reaching the brown to gray color indicative of mature seeds. Seeds may remain dormant in the soil for approximately 5 to 8 years following dehiscence (Selleck *et al*. 1962).

An important aspect of the biology of leafy spurge, in addition to production of large numbers of seeds, is the capacity of the plant to produce adventitious shoot buds directly from roots and crown. In young seedlings, shoot buds will develop within 10 to 15 days on the proximal portion of the hypocotyl and on the young primary and lateral roots. All

of these buds appear to have the potential to produce new shoots. The same is true of the buds located on the crown. If the above ground stem of the plant is killed by herbicides or mowing, these underground buds will be released, perhaps from the inhibition of prior apical dominance, to produce new shoots. The root system, which consists of both long and short roots, can give rise to shoot buds anywhere along its length.

The mature plant may have an extensive root system. For example, long roots have been excavated from a depth of 4.8 in (Selleck *et al*. 1962). Both the cultivation of the soil, which cuts or disturbs the root system, and mowing may actually increase the number of stems in an infestation. This was demonstrated by determining the density of leafy spurge before and after tilling the soil (Selleck *et al*. 1962). Shoot density increased from 134 shoot/$m^2$ in an undisturbed control patch of leafy spurge to 316 shoots/$m^2$ after tilling. Shoots can continue to emerge through 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).

Leafy spurge is difficult to control for a number of reasons. Although root buds have not yet been studied extensively in leafy spurge, they have been studied in other perennial species. For example, the common milkweed (*Asclepias syriaca*) also produces crown and root buds in a manner similar to leafy spurge (Stamm-Katovich *et al*. 1988). Uptake of the herbicide glyphosate in *Asclepias syriaca* in dormant buds proximal to the crown is minimal compared to those distal to the crown (Waldecker and Wyse 1985). These proximal buds will allow regrowth of the plant after herbicide treatment. The root system of leafy spurge extends very deeply into the ground and translocation of herbicides to deep buds is probably quite limited. Finally, the large number of seeds placed into the seed bank by leafy spurge populations ensures that plant replacement by seedling recruitment can occur on an annual basis.

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