

The Leafy Spurge Plant

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Leafy spurge (*Euphorbia esula* L.) is a dicotyledonous herbaceous deep-rooted perennial of the spurge (*Euphorbiaceae*) family. It is a difficult plant to control so the weed has spread steadily since its introduction.

Leafy spurge is widespread in continental Europe as far south as central Spain, Italy, and the Balkans, extending eastward through central Russia into Siberia (11). Leafy spurge apparently isn't a weed of economic or agronomic significance in its area of origin. The earliest report of the weed in the United States is a herbarium specimen collected in 1827 in Massachusetts. Leafy spurge has been known in North Dakota since 1909 (7). The weed was not recognized in western Canada until the early part of the 20th century (17). Early reports in Manitoba were from Russian Mennonite settlements where seed may have been in crop seed brought by them from Russia (7). The greatest abundance of the weed now is in the Northern Great Plains of the United States and the Prairie Provinces of Canada.

Flowers. The most conspicuous feature of leafy spurge is the yellowish-green flower-like clusters. The flowers (inflorescence) are borne on an umbel at the tip of the stem, or on lateral branches near the top of the stem. Each stalk (pedicel) of the umbel bears the unique flower of the spurge family known as a cyathium. Each cyathium produces one female (pistillate) and 11 to 20 male (staminate) flowers. Two opposite branches arise from the base of each cyathium, and each branch produces a cyathium. The process is repeated until the single original floral branch has divided into 8 to 16 branchlets (17).

The true flower parts are surrounded by cup-like bracts (involucre) of the cyathium (Figure 1). The yellowish-green bracts are the most colorful parts of the plant, but are not true male and female flower parts. The bracts generally appear two to three weeks before the true flower parts are functional. The sepals (calyx) and petals (corolla) are absent (7). The involucre surrounds a cluster of 11 to 20 stalked staminate flowers, each consisting of a single stamen, and one single-stalked pistillate flower (17). The stigmas of the pistil

open and become receptive to pollen from one to three days after emergence of the female flower. From three to eight days later, the glands of the cyathium begin secreting nectar. Then the pistil inverts by elongation of the pedicel, and one or two male flowers appear. On the day following inversion, from two to five male flowers appear, and the total of 11 to 20 male flowers appear within three days.

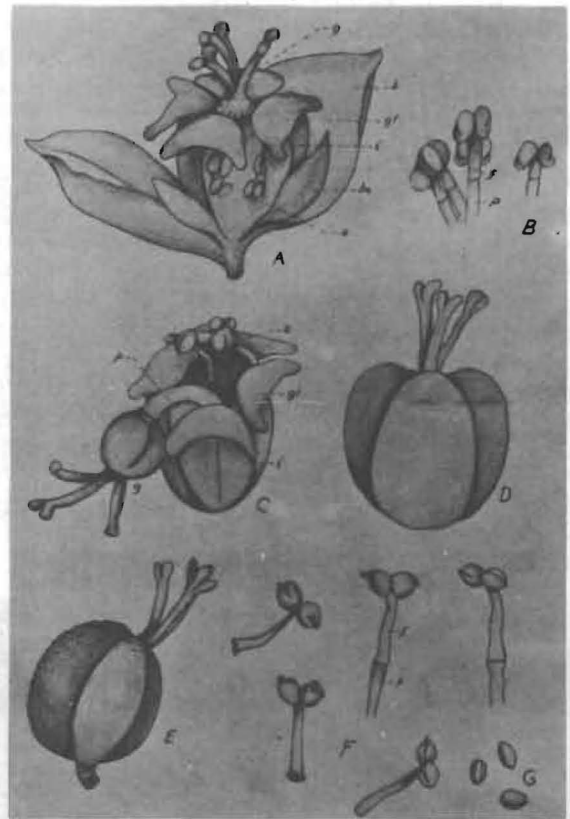


Figure 1. Floral parts and fruit of leafy spurge: A, the cyathium (flower cluster) surrounded by cup-like bracts (involucre); B, cluster of immature staminate (male) flowers; C, mature flower cluster showing pistillate (female) flower extruding from the involucre; D, mature fruit with all three carpels developed; E, mature fruit with only one carpel developed; F, stamens with anthers dehiscing; G, pollen grains; b, bract; bu, flower bud; f, filament; g, gynoeceium; gl, involucre gland; i, involucre; p, pedicel; s, stamen (from Hanson and Rudd 1933).

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Mature pollen is found on the anthers from 24 to 48 hours after emergence of the male flower, and is orange and sticky when ripe. Pollination apparently is almost entirely by insects. Ants, bees, flies, and mosquitoes have been observed feeding on the nectar and may be responsible for much of the pollination (17). The pollination mechanism in leafy spurge minimizes self-pollination.

The pistil is superior with a three-celled ovary (fruit). Nearly 50 percent of the fruits produce only one mature seed, about 35 percent produce two seeds, and only 15 to 20 percent produce three seeds (7). The ripe fruit dehisces explosively along the line of union of the carpels. The explosive action of the ripe fruit throws the seed up to 15 feet from the plant.

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 (17). Flowering generally ceases in terminal inflorescences between late June and mid July. The development and maturation of seeds extends approximately 30 days beyond the appearance of the last flower. Generally, the first viable seed is produced by late June and most of the seed matures during July, but small amounts of seed can be produced in August and until frost.

Seeds. Seeds are silvery gray to light gray tinged with purple (7, 10). There is a prominent yellow-colored protrusion, called the caruncle, at the narrow end and a brown line extends from the caruncle to the opposite end (Figure 2). Seeds go through several color changes during development from yellow through orange and brown to gray at maturity (8, 18). Seeds are viable by the brown stage, which occurs 10 to 13 days after fertilization depending upon seasonal conditions. Leafy spurge control to prevent viable seed production must be done before the seeds have turned brown. The approximate seed maturity can be determined by breaking the fruit open to observe the seedcoat color.



Figure 2. Leafy spurge seed. Note the caruncle at the narrow end and a brown line extending from the caruncle to the opposite end.

Seed germination in the laboratory was most rapid at alternating 68 to 86°F, intermediate at constant 86°F and slowest at constant 68°F (7). Field germination of seeds in the spring follows several days of air temperatures of 78 to 82°F (17). Most seeds germinate in the spring, but some seeds will germinate throughout the growing season. Under favorable conditions, 99 percent of the seeds will germinate or be destroyed within two years, and the remainder either germinate or deteriorate within eight years.

Seed dispersal begins when the mature capsule dehisces, hurling the seed up to 15 feet and distributing them uniformly (7). Seeds can float for several hours on runoff water or streams which facilitates spread. Wild and domestic animals, birds, and insects are agents of dispersal. Birds as primary disseminators of leafy spurge seed have been suggested because of frequent feeding and frequent occurrence of new patches under trees and fences. Viable seeds have been found in the droppings of some birds, such as the sharptail grouse. Seeds probably move with mud on animal feet or hair. Some leafy spurge seeds can occur in sheep manure, and probably can occur in the manure of other animals. Seeds also move on machinery and in hay.

Seedlings. The plant emerges by elongation of the hypocotyl, and the seed leaves (cotyledons) function as the first leaves (Figure 3). The first true leaves generally develop within 6 to 10 days after emergence (17). The first true leaves are opposite, but the subsequent leaves are distinctly alternate. Most seedling emergence occurs from 0.5 to 2 inches soil depth, although germination can occur from the surface to 4 inches deep (17).



Figure 3. Seedlings of leafy spurge. The cotyledons are at the first node, a pair of opposite leaves at the second node, and subsequent leaves are alternate.

Seedlings develop perennial characteristics rather quickly. Of 22 seedlings in the six-leaf stage which were cut 0.5 inch below the soil surface, 11 produced new shoots (17). All of the seedlings in the 10-leaf stage survived when severed at the 0.5 inch depth.

Seedling survival generally is low, especially with competition (7, 17). Selleck et al. (17) reported 2340 seedlings per square yard on May 27, 1951 in a natural infestation, but 82 percent of the seedlings had died by September 12.

Stems and leaves. Stems usually are erect, 16 to 32 inches high, and unbranched except for the flowering umbel. However, axillary buds frequently develop into branches when the stem tip has been injured. The stems become woody toward the base, so the dead stem remains standing for a year or more. Stems are pale green in summer but become yellow to red in the fall.

The density of leafy spurge stems varies greatly among stands and can fluctuate greatly from year to year with changing environmental conditions. In most situations, the number of stems does not increase when a density around 165 stems per square yard is reached (17). However, densities over 800 stems per square yard have been recorded.

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 (11). 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 (7).

Roots. The most important part of the plant for leafy spurge control is the root system and associated vegetative buds (Figure 4). There are numerous coarse roots that occupy a large volume of soil. The roots are



Figure 4. Roots and vegetative buds of leafy spurge. A crown has developed at the stem base showing last years stem, a growing stem, and numerous buds to produce future stems. The horizontal root can produce new root or shoot buds at almost any point on the root.

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 six years during the development of plants (17).

The horizontal underground structures are roots and not underground stems (rhizomes) (12). 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 (13, 14). "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 new lateral long roots and shoot buds that account for the vegetative spread of leafy spurge patches. Short roots do not produce shoot buds but are important for water and nutrient uptake.

Roots of leafy spurge have great capacity to produce new shoots from various depths. Coupland et al. (4) covered leafy spurge roots with 1, 2, or 3 feet of weed-free soil using two methods, (a) piling and tamping soil to the desired depth on top of a leafy spurge patch, and (b) excavating all the soil in a leafy spurge patch to the desired depth and tamping clean soil over the remaining roots. Shoots at all locations penetrated 2 feet of soil within 12 months, and some shoots emerged through 3 feet of soil. 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 five successive years from a depth of 3 feet after the major portion of the root system had been removed by excavation. Hanson and Rudd (7) observed emergence of new shoots after roots had been killed to a depth of 1 foot or more by sodium chlorate (Figure 5). Leafy spurge control treatments such as herbicides or tillage must kill the root system at least 3 feet deep to prevent emergence of established plants, or treatments must be repeated until deep root food reserves are depleted.

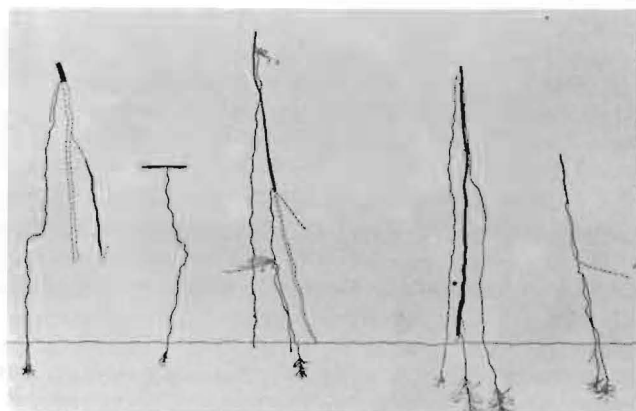


Figure 5. Shoots of leafy spurge arising from roots treated with sodium chlorate. Note the killed root parts indicated by broken lines and new shoots arising from surviving roots at depths of 1 foot or more (from Hanson and Rudd 1933).

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 (3). The average number of buds per root in excavations was 35 to 272 in different plant 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 (13). 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. Additional shoots may arise later 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 portion have died back (13). 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 perennial survival of leafy spurge. Moreover, they give rise to adventitious roots, some of which are spreading long roots that contribute to the vegetative spread of the plant.

Latex and chemical properties. Latex is present throughout the plant from the root to the shoot (1). 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 of the seed (7). The latex has been evaluated as potential rubber or energy sources, but these alternative uses seem impractical for the foreseeable future.

Leafy spurge contains a toxic substance that, when taken internally, is an irritant, emetic and purgative. It causes scours and weakness in cattle and may result in death (17). The toxin has produced inflammation and loss of hair on the feet of horses from freshly mowed stubble during haying (9) and has caused mortality of sheep in Alberta (8). Animals will eat the dried plant in hay, but livestock, particularly cattle, avoid eating growing plants.

There is indirect evidence that leafy spurge has allelopathic properties, i.e., the weed releases chemicals that inhibit the growth of other plants in the same area. For example, the small number of forbs in patches of leafy spurge, even when bare ground is visible between shoots, suggests that this species exerts inhibitory effects on other plants (16). However, specific chemicals have

not been identified to verify the occurrence of allelopathy.

Genetic diversity. Leafy spurge generally is identified as *Euphorbia esula*, but its correct botanical identity is uncertain. Richardson (15) in 1968 identified leafy spurge as *Euphorbia podperae* Croiz. Dunn and Radcliffe-Smith (5) in 1980 examined 28 herbaria sheets of leafy spurge from 12 states and identified five morphologically separable taxa. However, Ebke and McCarty (6) in 1980 established leafy spurge from 36 locations across the northern United States and Canada and reported that most of the collections separate into a single taxa: *Euphorbia* × *pseudovirgata*, a hybrid of *E. esula* and *E. virgata*. Regardless of the correct taxonomic identification, there has been evidence that the genetic diversity in leafy spurge may limit the suitability of some diseases and insects as potential biological control agents. Galitz (unpublished data) at North Dakota State University recently observed a highly virulent fungal growth on one leafy spurge biotype among approximately 15 selections in the greenhouse; the fungus apparently is a powdery mildew. Dunn and Radcliffe-Smith (5) reported that a clear-winged moth (*Chamaesphecia tenthrediniformis*) collected on leafy spurge in Switzerland and Austria failed to become established on leafy spurge in either Canada or the United States. The genetic diversity of leafy spurge may represent an important barrier to successful establishment of some leafy spurge control programs, particularly biological control with insects and diseases.

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Other landowners recognize that leafy spurge can be controlled with herbicides, if not eradicated, by using some of the chemical control alternatives described in the accompanying article by Lym and Messersmith. I have observed several ranches where the owner treats the leafy spurge patches every year, and the contrast with neighboring untreated pastures for both weed density and area infested is visually striking and convincing that control is possible.

The frustration with herbicides for leafy spurge control has kindled a strong public interest in alternative control methods. Biological control may be the answer. Leafy spurge seems to be a good candidate for biological control, but there are many problems to be solved as addressed in the article in this issue by Carlson and Littlefield. It probably is a realistic estimate that four to six insects and/or diseases will have to be established on leafy spurge before a successful biological control program is in place. It probably will take 20 years to reach that goal.

Any program to control a weed depends on obtaining a thorough understanding of the basic biology of the weed. There have been extensive studies concerning the general growth and development (anatomy and morphology) of leafy spurge, but studies of life processes at the cellular level (physiology) are very limited. There is some indication that the strains of leafy spurge

prevalent in North America are substantially different from the strains most prevalent in Europe. Insects and diseases often are adapted to specific strains of a plant. Thus, research that develops a clear understanding of the strains of leafy spurge in North America may be a critical step to establishment of a viable biological control program. Many voids in our knowledge about the basic biology of leafy spurge are addressed in an article by Galitz and Davis.

The priority for integrated leafy spurge control research is recognized by the agricultural research administration and legislative leaders. The Agricultural Experiment Station has redirected some staff scientists from their former projects to biological control research. Also, the 1983 North Dakota Legislature is considering a request to add scientific, technical and financial support to the leafy spurge integrated control program; the indications are that the request will be approved although the Legislature still is in session at this writing.

"From Yellow to Green" could be the motto of the leafy spurge control project at NDSU, because our goal is to replace the yellow flowered leafy spurge plants so prevalent in June with luscious green grass on many acres of North Dakota. Hopefully, the goal can be attained in 20 years as a realistic estimate, although we all dream of and will work for a quicker solution.