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The biology of leafy spurge

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The Federal Noxious Weed Act of 1974 states that a noxious weed is:

> "any living stage (including, but not limited to, seeds and reproductive parts) of any parasitic or other plant, of a kind or subdivision of a kind, which is of foreign origin, is new or not widely prevalent in the United States, and can directly or indirectly injure crops, other useful plants, livestock, or poultry or other interests of agriculture, including irrigation, or navigation, or the fish, or wildlife resources of the United States or the public health."

Leafy spurge falls into this category, and as such is required by law to be controlled or eradicated, where infestations occur.

This is a review of some of the more important aspects of the biology of leafy spurge, that relate to its aggressive nature, and an understanding of which might lead to its ultimate control or eradication.

Over the years, there have been a few reviews of the biology of leafy spurge. The first to appear were the North Dakota Experiment Station report by Hanson and Rudd in 1933, entitled **Leafy Spurge, Life, History and Habits**, and an Iowa Experiment Station bulletin, Leafy Spurge, (*Euphorbia esula*) by Bakke, in 1936. These included a good basic description of the phenology and the biology of leafy spurge, as it was known at the time. In 1962, Selleck, Coupland, and Frankton published **Leafy Spurge in Saskatchewan**, an ecological monograph which reviewed the biology of leafy spurge and its adaptation to the environment of Saskatchewan. In 1978, Galitz conducted a computer data base search of all the literature on the biology of leafy spurge and wrote a summary which was published as a departmental report.

In 1983, Galitz and Davis published **Leafy Spurge Physiology and Anatomy**, a brief review of some of the biological characteristics of leafy spurge which they considered to be salient to spurge being as troublesome a weed as it is, and more recently, 1985, Mess-

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ersmith, Lym and Galitz wrote **The Biology of Leafy Spurge**, a chapter included in "Leafy Spurge", a monograph published by the Weed Science Society of America. These reviews immediately point out why leafy spurge, without a predator or some suppressing factor, has flourished and become the noxious problem that it has. It is an extremely competitive plant, that can eliminate other species once it invades a plant community and becomes established. It is hardy, has a rank growth habit, is capable of growing vigorously in diverse environments, is a prolific producer of seeds with varying dormancy periods (which ensures a long lasting soil seed reserve) is able to reproduce vegetatively as well as sexually, is stress resistant and can, in mid to late summer, be revived with a second flush of growth and production of a second generation of seed. Lastly, because of its capacity to produce large quantities of latex, it is avoided by most livestock and wildlife as forage or browse. I will discuss a few of the physiological characteristics of leafy spurge which I think are important for this strategy planning conference.

Recognition of leafy spurge

Fifteen years ago, at the first Leafy Spurge Symposium held in Bismarck, North Dakota, this weed was recognized only by a relatively few number of plant scientists, who were working on the problem, weed scientists and control officers, and land owners who's properties were infested with the weed. Today, due to a substantial educational effort, a large sector of the population, in states where spurge is a problem, readily recognizes the plant up close and also from a distance. Many people now spot it from the road as it grows in a variety of environments and appreciate it for the problem that it poses.

From early in the spring until mid summer, and then frequently with a second flourish of growth later in the summer, a spurge patch is characterized by its unusual yellowish-green, almost chartreuse, appearance, which is due to the coloring of its floral structures. The flower consists of an umble that develops at the apical meristem, and which produces a pair of opposite branches. Each branch can subdivide to produce a pair of opposite branchlets, and this subdividing can continue for a dozen or more times. Each branchlet produces a pair of yellowish-green bracts. The color of these structures is what makes a blooming patch so recognizable from a distance. Each branchlet of the umble produces a cyathium which has a single pistil, containing a three chambered ovary on a stalk. The pistil is surrounded by dozen or more stamens, each with a single anther. The flowers are surrounded by an invulcre which consists of five bracts and four nectar glands.

The view of a leafy spurge patch is not unattractive, nor does it appear to be ominous. Therefore, the question regarding this insignificant appearing plant is "What are the characteristics of this plant that make it so troublesome and noxious?" To answer this, one only needs to look at some of the characteristics of the plant.

Characteristics of leafy spurge

Seed production, germination and viability: A leafy spurge plant will produce a couple hundred seeds with its first bloom each year. A much smaller number is produced

after the second bloom, if, in fact, any seeds actually mature. This is not a very large number compared to some species such as ragweed, which may produce several hundred thousand seeds per plant. Also, the seeds are relatively large, weighing about a fourth of a gram or 250 milligrams. The seeds also have an innate dormancy. The literature reports that in germination tests, a given lot of seeds may give less than 10% to as great as 40% germination. Because of this modest germination rate and a fairly long retention of viability, a seed reserve in the soil may persist for 8 to 10 years. Thus elimination of vegetative plants does not necessarily solve the weed problem.

Best germination occurs under cool moist conditions, and may take up to two weeks.

Seedling establishment: Selleck and other researchers have reported on emergence, the rate of growth of seedlings, and comparisons of shoot to root production. Ten days after germination, the shoot of a seedling may be only a couple centimeters in length but examination of the root system gives one an indication of a potential problem with leafy spurge. The root may already be ten centimeters long, giving a root/shoot ratio of at least 5/1. This ratio may continue to expand till the plant reaches vegetative maturity, making spurge a strong competitor for both water and nutrients.

Growth habitat: It has been noted that leafy spurge has been recorded to invade and become established in a wide variety of environments. It is especially quick to invade disturbed areas. It is readily found along road sides and rail right-of-ways, open range, and wooded areas. Spurge can also be found in contrasting situations such as moist marshes as well as dry prairie, in open sunny areas or in the shaded understory of a floodplain, on northern slopes and on southern slopes. In addition to its westward migration since its introduction to the east coast decades ago, spurge has also shown a gradual southerly migration. Fifteen years ago Nebraska was thought to be the southern limits for spurge. Today, there are reports of its occurrence as far south as Missouri and New Mexico. In the final analysis, there has not been a good ecological study conducted to determine the limiting parameters in the geographical distribution of leafy spurge in the United States.

Growth habits

1. Early shoot emergence. Early shoot emergence from crown and root buds may occur as soon as the ground thaws. It may be as early as mid April. As will be discussed later, these shoots develop from dormant crown and root buds in the autumn, but remain underground or beneath the surface debris, in a cold hardened state. When the ground temperature becomes high enough to support growth, they begin to emerge. This gives them a distinct competitive advantage over other plants in the plant community.

2. Rankness: Rank growth is defined as luxuriant and vigorous. While leafy spurge is very vigorous, it is not necessarily luxuriant. A bad infestation may have a high number of stems per square meter and many leaves per stem, but because of the small leaf area and the shape of the leaves the leaf area index is not be very great.

3. Root growth: The profile of the root system of leafy spurge indicates a long primary tap root from a very early stage of development. There are numerous secondary vertical roots and well developed lateral roots. Shoot buds are found throughout the root

system. Also, additional root buds can be found on the horizontal roots. During the growing season, while the shoots are physiologically active, the growth of these buds appears to be suppressed by the plant hormone indoleacetic acid, auxin, in accordance with a phenomenon known as apical bud dominance. When the shoot senesces at the end of the growing season, the source of auxin declines and the dormant buds begin to elongate. At the end of the season they will have reached the surface of the soil and will have become cold tolerant.

4. Colony expansion: A colony, with a diameter of thirty feet, may consist of a network of horizontal roots interconnecting the vertical root masses that support the various stems. Because of seed germination, the roots of newer individual plants will also be found, creating a very complex system. A spurge patch may have an annual increase in its radius by up to three meters in a good growing season.

5. Regrowth potential: Because the root and crown buds are developed very early in the season, any damage to the shoots, caused by grazing, mowing, fire, chemical burning, etc., will release them from shoot suppression, and rapid regrowth occurs.

6. Variability: There is considerable variability amongst the collections of leafy spurge from different sites. These have been referred to as accessions and also as biotypes. While phenology can be partly altered some by the growing conditions and the environment, the variability between accessions is genetic. This variability can be seen in the number of stems that emerge from a crown, the height of the stems, the size and the shape of the leaves, and the number and location of stomatal pores. Metabolic differences have also been demonstrated, such as differences in resistance to herbicides and the production of terpenoid compounds in the latex of the plants.

7. Laticifer system: The laticifer system is an anastomosing network of tubules throughout the plant, in which large quantities of latex are found. This system is intermingled with but is entirely separate from the vascular system, xylem and phloem and which conducts water, minerals and various assimilates throughout the plant. This latex acts as a repellent to most animals which might otherwise graze in the area were spurge not present. The components of the latex may be a factor in determining the extent of success in establishing insect populations for bio-control.

8. Allelopathy: The phenomenon of allelopathy involves the production of substances, called allelochems, by one plant, that inhibit or reduce the germination and/or growth of another plant species. Evidence has been reported that leafy spurge may become a dominant species in an ecosystem partly because of the production of allelochems by the spurge plants.

We have also reported that a plant known as small everlasting, (*Antennaria microphylla*), can grow adjacent to a leafy spurge patch but does not become invaded by the spurge. Experiments indicate that small everlasting produces allelochems that have biological activity, inhibiting the growth of spurge.

9. Stress resistance: It is well established that leafy spurge is able to withstand considerable water stress by avoidance. Because of its long tap root system, it is able to absorb water from greater depths than other plants in the community. Under severe stress

conditions, tissue dormancy is also a mechanism by which spurge plants are able to resist stress.

Through a considerable amount of coordinated and collaborative effort on the part of many scientists, there are a number treatments available that work, to varying degrees, in controlling the emergence, growth and maturation of the shoots of leafy spurge. These include mechanical, chemical and biological methods. However, to eventually reduce the intensity of a spurge infestation, it is absolutely essential to reduce the vigor of the root system and the development and growth of crown and root buds. Until we can accomplish that, we will continue to struggle with this perennial problem.

Crown and root bud regulation

My laboratory has been studying the regulation of crown and root bud growth in leafy spurge for several years and have finally developed a model to explain observations and the various facts we have in hand. The following data are from several investigators.

1. Plant observations:

   A. Crown and root buds are produced early in the growing season.

   B. These buds are initially dormant and do not grow.

   C. By late summer or early fall, the stems begin to senesce, or at least are not very physiologically active.

   D. By the end of the growing season, the crown buds in particular, have broken their dormancy and have elongated till their tips are just below the surface of the soil or the ground litter.

   E. The tips of these buds are usually pink and contain anthocyanin pigments.

   F. The tissues have started perennating and become cold hardy.

   G. It has been demonstrated that hydrolytic enzymes, such as the amylases and proteases are activated at this time so that there will be a gradual mobilization of carbohydrate and nitrogen reserves during the winter months.

   H. Electron micrographs of apical meristems of crown buds, that have been induced to elongate under laboratory conditions, show that amyloplasts (starch granules), and liposomes (oil droplets), rapidly disappear with the commencement of growth.

   I. Exogenously applied plant hormones, gibberellic acid in particular, has enhanced bud elongation in some instances.

   J. We have good evidence for the existence of a phytochrome system in the crown bud tissues of leafy spurge.

2. Environmental observations:

   A. There are changes in day length and the intensity of the sunlight.

   B. There is a change in the quality of the sunlight. (the ratio of red/far-red light)

C. There are changes in the mean day and night temperatures.

3. A Model for the regulation of crown and root bud growth.

A. With senescence of the stems in the autumn, they cease producing auxins, and the endogenous levels throughout the plant decrease.

B. Crown buds are released from the apical dominance of the shoots and begin to elongate.

C. As the tips of the buds reach the surface of the soil or near the top of the ground litter, a phytochrome in the tips of the buds perceive the red/far-red ratio of the autumn sunlight. The prevailing ratio converts the phytochrome to a physiologically active form.

D. The activated phytochrome elicits several responses:

1) causes the etiolation of the crown bud, which includes the cessation of elongation.

2) may induce the cold hardening of the crown buds.

3) regulates the synthesis of the active forms of gibberellic acid.

E. The active gibberellins regulate the synthesis of hydrolytic enzymes such as alpha and beta amylase and proteases.

F. During the winter months, these enzymes gradually degrade the carbohydrate and nitrogen reserves in the roots so that in the spring, the buds can resume growth as soon as the temperature will allow.

This model, if accurate, explains the definite advantage that leafy spurge has, in resuming growth before the dormancies of other plants are broken or seeds of other species can germinate. Modification of these events could lead to a strategy which would significantly reduce the severity of existing spurge infestations and prevent invasions of new areas from ever becoming severe.

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