The Knapweeds: Their Economics and Biological Control in the Western States, U.S.A.

D.M. Maddox

Editor's Note: We have two interesting articles in this issue on the troublesome knapweeds. Before we could publish the one by D.M. Maddox of California we received another from R.M. Strang of British Columbia. They are both worthy of publication. The first tells about biological control whle the second discusses the weeds in general. Purpose of the articles is to bring about greater public awareness to eliminate unintentional and avoidable spread of the undesirable knapweed pest.

Introduction

Diffuse and spotted knapweed, *Centaurea diffusa* Lam. and *Centaurea maculosa* Lam., are rapidly becoming the most economically important rangeland weeds in the Pacific Northwest. Diffuse knapweed is estimated to infest 756,000 acres in Washington, 750,000 in Oregon, and 73,000 acres in Idaho; spotted knapweed infests about 2,000,000 acres in Montana and 80,000 acres in both Idaho and Washington. Together they infest a conservatively estimated 3,659,000 acres in the four states. There is a strong suspicion that both weeds were introduced to North America in alfalfa seed, either from Asia Minor–Turkmenistan (an area where both diffuse knapweed and alfalfa are native), or with hybrid alfalfa seed from Germany.

Although treatment with picloram will control these weeds, the cost is often prohibitive, the chemical may have undesirable side effects, and the stability of the material is such that it may harm economically important crops. Monetary losses due to these knapweeds are sufficiently high to warrant serious attention.

Current research shows that biological control is a viable option that poses no threat to the environment and promises long-term self-perpetuating impact on the weeds. This method is particularly suitable for controlling weeds on lands that are extensive and/or of low economic value, such as those infested by the knapweeds. A fly and a moth that attack the seeds and two insects that attack the crown of the knapweeds are prospective control candidates. There is a real need for "Action Committees" of concerned individuals to deal with weed problems on rangelands.

Economic Benefits versus Losses

Benefits. All plants serve some useful function in nature though it may sometimes be contrary to the interests of mankind. Both diffuse and spotted knapweeds establish very rapidly in available habitats and are valuable pioneer species. Spotted knapweed is considered a biennial, sometimes perennial plant, while diffuse knapweed behaves either as an annual, biennial, or short-lived perennial. The rosettes of both species produce a useful plant cover on barren soil, thus preventing soil erosion. The flowers reportedly provide substantial pollen and nectar for bees, and the seeds may provide some sustenance for birds and rodents.

Losses. Substances in the stems and leaves of knapweed prevent the growth of other plants, with the result that knapweed tends to form solid stands. This growth habit is a serious problem for the rancher because knapweed plants have little nutritive value and high fibre content. High levels of consumption of either diffuse or spotted knapweeds can cause toxic symptoms, especially in horses.

The dollar loss caused by knapweeds on western rangeland can be considerable. In northeastern Oregon the carrying capacity on good knapweed-free rangeland is estimated to be about 0.27 Animal Unit Months per acre (or 3.75 acres per Animal Unit Month) (AUM) for the 8-month grazing season. The income from such rangeland is estimated to average $7.50 per AUM with a range of $5 to $10. On similar rangeland that is infested with knapweed, the carrying capacity is about 0.16 AUMs per acre. This 0.11 AUM difference represents a loss of about $0.80 per acre for the grazing season. The total loss represented by the 750,000 acres of knapweed-infested rangeland is $600,000 annually.

Other losses caused by knapweeds include increased maintenance costs (to repair fences when knapweeds break off, tumble, and pile up against them) and decreased market value of the land. For example, in Oregon, where the land is taxed on its income producing ability, knapweed infestations decrease both market value and production value. In many cases the market value of such land is $40 to $60 per acre, but when the same land is infested by knapweed it may be appraised as low as $3 to $4 per acre.

Chemical Control: Cost and Effect

What is the cost of chemical control and how effective is it? A quarter pound of picloram per acre will effectively control both diffuse and spotted knapweed. However, the applied cost of $15 per acre is prohibitive, especially since knapweed infestations occur extensively on land of low economic value. Theoretically, if

The author is a research entomologist, Biological Control of Weeds Laboratory, Science and Education Administration-Federal Research, United States Department of Agriculture, 1050 San Pablo Avenue, Albany, California 94706.

the estimated acreage infested by both species (3,659,000 acres) was treated with picloram, it would cost $54 million. Other limiting factors to the use of picloram are (1) It is extremely stable and so is a potential danger to cultivated crops, even after it passes through a cow's digestive tract; (2) Treatment of infestations that are adjacent to water would not be permitted; and (3) Retreatment is still necessary at periodic intervals. Less expensive herbicides such as 2,4-D may be used, but repeated treatment would be necessary to gain acceptable levels of control. In fact, any chemical treatments of such an extensive acreage is unlikely, because of the formidable cost factor.

Biological Control of Knapweeds

Biological control is control of an undesirable weed or other pest by using its natural enemies (e.g., insects, mites, and pathogens). In their native environments most higher plants have natural enemies that feed on their roots, stems, leaves, and floral parts. When these plants are taken to a new environment, free of their natural enemies, they may become abundant and weedy.

Several steps are necessary in achieving biological control of weeds. First, there is exploration for natural enemies in the native areas of the target weed. Candidate enemies uncovered by exploration must then be tested to determine their food plant preferences. If they are host specific, they may be approved for introduction into the problem areas. Subsequent successful establishment and increase then depends on variables such as host plant quality, favorable climate, synchronization with the host plant, and the absence of parasites.

In the case of knapweeds, the exploration was done by Dr. H. Zwolfer at the Commonwealth Institute of Biological Control Laboratory in Switzerland on behalf of Agriculture Canada. He found a complex of natural enemies but focused his attention on the fly *Urophora affinis* which attacks the seeds of the knapweeds. Releases of the fly were begun by Canada in 1970.

The initial effort to use *U. affinis* against diffuse and spotted knapweeds in the western United States was made in the summer of 1973. Seed heads of spotted knapweed containing

Female Urophora affinis *resting on diffuse knapweed bud. Arrow indicates long, terminal ovipositor for depositing eggs.*

Developing larva of Urophora affinis *in partially opened gall in seed head. End of gall has been removed to show the larva. The larva passes the winter inside the gall.*

developing flies were collected from the Rhine Valley in France during November 1972 by the USDA Biological Control of Weeds Laboratory at Rome, Italy. The flies were shipped to the USDA Biological Control of Weeds Laboratory at Albany, California. The first releases in the western states were made in 1973, when about 1,000 flies were released on spotted knapweed in the Bitterroot Valley near Corvallis, Montana, and about 1,600 flies on diffuse knapweed near Heppner, Oregon. Subsequent releases of more than 22,000 flies were made in the states of Montana, Oregon, Idaho, Washington, and California over the last 5 years.

The female seed fly lays her eggs in the small knapweed buds with a long ovipositor (see photograph). The newly hatched worm-like larva soon forms a woody structure called a "gall" in which it develops. The result is that the nutrient resources of the plant are diverted into gall formation and as a consequence fewer heads are developed. The larva overwinters inside the flower head and completes its development and emerges as an adult the next season when new buds appear on the host plant. Usually only one generation of flies is produced annually.

To date the fly has become established at all sites where it has been released, and although it is dispersing slowly from the release areas, the populations are still low. At the release site, Okanogan County, Washington, nearly 2 galls per seed head have been found. Collection and redistribution of flies to new areas should be delayed until the population has increased.

Future Plants for Biological Control

Because of the immensity of the knapweed problem and the potential of these weeds to spread, research plans include finding, testing, and introducing additional natural enemies. Two root-boring insects, one a beetle and one a moth, are being considered, plus a moth that also attacks the seeds. The root beetle and seed moth have already been released in Canada. Also, a stem gall fly has been reported on diffuse knapweed in the U.S.S.R., along with a plant pathogen, *Puccinia* sp. (rust), which can be damaging.

It has been estimated that the direct cost studying and introducing several weed-feeding insects for biological control may run $1-1.2 million and take about 11.5-12.5 scientist years. However, if biological control could reduce the knapweed infested acreage by 50%, these costs would be recovered manifold in just a few years.

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Knapweeds: British Columbia's Undesirable Aliens

R.M. Strang, K.M. Lindsay, R.S. Price

Introduction

Knapweeds were introduced into Canada from their native Eurasia in shipments of alfalfa seed about the turn of the century. Since growing conditions in the dry interior of British Columbia are very suitable for them, they are spreading vigorously, so vigorously that they pose a major threat to the rangelands and ranching industry of the Province.

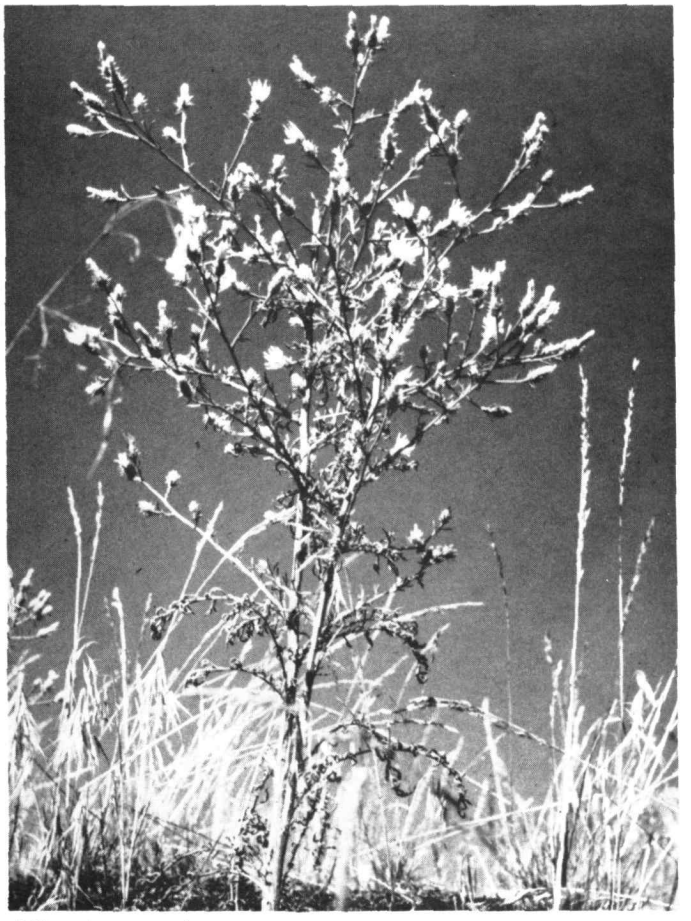
It has been estimated (Harris and Cranston 1979) that knapweed infestation is now causing annual losses of range production worth $900,000; that it is increasing at about 10% a year in B.C.; and that 10,000 ha are susceptible to invasion in Western Canada. Parts of the U.S., especially Montana, are also seriously affected.

Location

Interior British Columbia is a steeply dissected, rolling peneplain lying between the Coast Mountains to the west and the Columbia/Rockies chain to the east. The northern limits of the ranching area, at about Lat. 55°N, are the Skeena and Omenica Highlands. Lying in the rain shadow of the coastal mountains, the area is dry and fairly hot, with availability of soil moisture limiting growth, but local climate is strongly affected by elevation and aspect. Precipitation may be as low as 20 cm annually and frost-free days range from 180 to 110. Soils are chernozemic in the valley bottoms changing up-slope to luvisols or brunisols. Bluebunch wheatgrass is the climax dominant in the valley bottom grasslands; above this one finds open ponderosa pine/-bunchgrass forest and, still higher or further north, Douglas-fir/pinegrass. These climax communities have been much changed by heavy grazing, logging and burning. They now constitute the ranching area of the Province, providing some 800,000 AUM's of grazing each year.

Plant Characteristics

The knapweeds are members of the Centaureinae subtribe in the Compositae, the sun-flower family. Diffuse knapweed (*Centaurea diffusa* L.), usually a biennial, grows rapidly in its second summer from an overwintering rosette form to a stalk about 80 cm with 70–80 white or occasionally purple flowerheads on each plant. Since 10–15 seeds are produced in each flowerhead, up to 1,000 seeds can develop on a single plant (Fig. 1). Spotted knapweed (*C. maculosa* L.) too, is mostly biennial but pro-



Diffuse knapweed

The authors are associate professor (rangeland ecology) and senior forestry undergraduates, Faculty of Forestry, University of British Columbia Vancouver V6T 1W5.