References

Andres, L.A. 1976a. The economics of biological control of weeds. Aquatic Botany, 3:111-23.

Andres, L.A. 1977b. The biological control of weeds. p 153-76 *In:* Integrated Control of Weeds, J.D. Fryer and S. Matsunaka (Eds.) Univ. of Tokyo Press, Tokyo.

Englert, W.D. 1974. Revision der Gattung *Metzneria* Zeller (Lepidoptera: Gelechiidae) mit Beitragen zur Biologie der Arten. Z. Ang. Entomol. 75:381-421.

Watson, A.K., and Renney, A.J. 1974. The biology of Canadian weeds, *Centaurea diffusa* and *C. maculosa*. Can J. Plant Sci. 54:687-701.

Zwolfer, H. 1970. Investigations on the host-specificity of *Urophora affinis* Frlfld. (Diptera, Trypetidae) Prog. Rep. Commonw. Inst. Biol. Control No. 25. 28 p.

Knapweeds: British Columbia's Undesirable Aliens

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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.

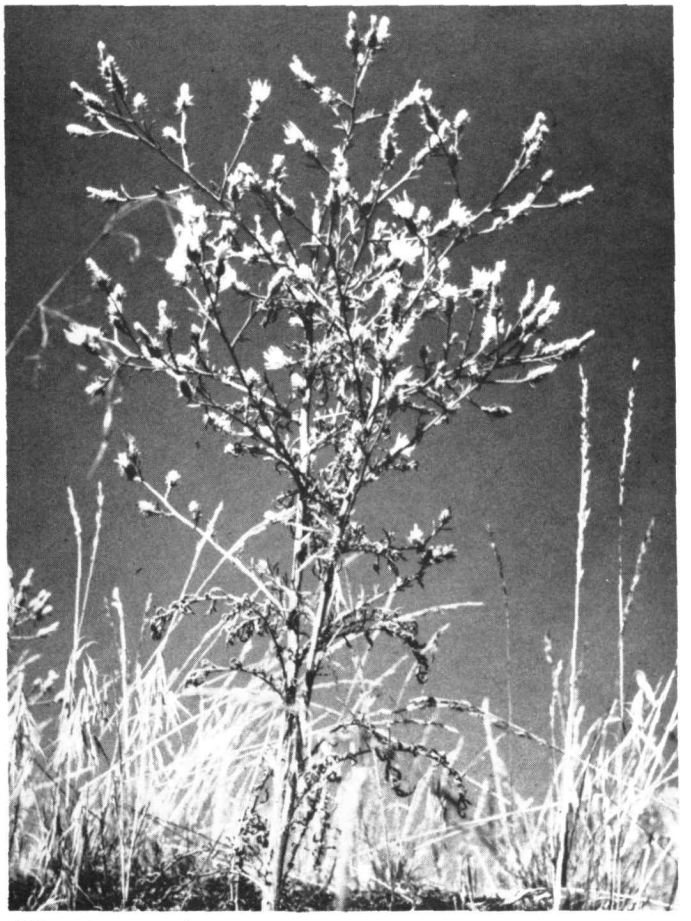
It has been estimated (Harris and Cranston 1979) that knapweed infestation is now causing annual losses of range production worth $900,000; that it is increasing at about 10% a year in B.C.; and that 10,000 ha are susceptible to invasion in Western Canada. Parts of the U.S., especially Montana, are also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

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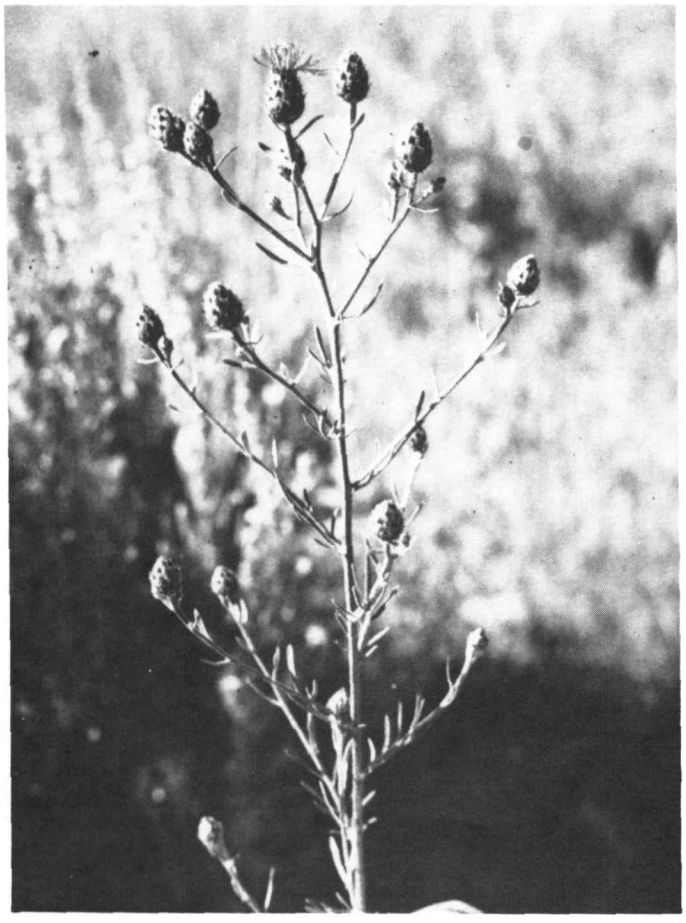

Spotted knapweed

duces only half as many seeds—25–30 on each of 15–20 purple flowerheads (Fig. 2). Russian knapweed (*C. repens* L.) has also been introduced, but it is a relatively insignificant pest (Watson and Renney 1974). A fourth species, black knapweed (*C. nigra* L.), has also been noted but it is very limited in its distribution.

Knapweeds are pioneer species, taking hold quickly and thriving on disturbed dry sites but only rarely on burned areas. Diffuse knapweed is spread most commonly when the mature plant dies, breaks off at the rootstock, and is blown or carried away, to shed seed and give rise to a new population where the dry plant comes to rest. Individual seeds can easily become attached to passing animals and thus transported. Spotted knapweed, which grows in cooler, more moist sites than the diffuse species, spreads, less dramatically, by flicking its dry seeds, called achenes, up to 1 m from the parent plant. It is also spread by birds, small mammals, and ants.

Spread and Competition

Spotted knapweed was recorded from Victoria in 1893 by the botanist and explorer Macoun. In 1907 it was reported in Klitekat County, Washington, and by 1930 it was known in B.C. at Pritchard and Lytton (Renney 1959). Within 20 years knapweeds were widespread in the Okanogan (sic) and were spreading in the Grand Forks and Cranbrook/Kimberley areas. By 1952 it was estimated (Watson and Renney 1974) that there were about 100 ha of diffuse and 120 ha of spotted knapweed in the Thompson and Nicola River catchments. These areas had increased to 26,000 and 3,400 ha respectively by 1974. Now, knapweeds are present as far north and west as Prince George and Tatlayoko Lakes. Harris and Cranston (1979) estimate that almost 11 million ha in western Canada have a soil and climatic environment into which knapweeds could easily spread and flourish if they are not controlled.

Animals only occasionally eat young plants and they avoid mature specimens, which are harsh and spiny. Thus, since it is not grazed, knapweed spreads at the expense of forage species. It has also been established (Fletcher 1961; Fletcher and Renney 1963) that once knapweeds have grown in a soil, that soil will for some time not support other species, amongst them at least one grass, barley. This inhibitory effect, called allelopathy, appears to be a second factor which contributes to reduction of forage production once knapweed has become established. Competition for available soil moisture probably also reduces forage yields.

Good bluebunch wheatgrass range in the Kamloops area of B.C. has an average annual production of up to 1,000 kg/ha when in excellent condition. When knapweeds are present, the yield may drop to as little as one tenth of this, or only 60 kg available forage per ha. Because of past mismanagement, not many ranges are in excellent condition; nevertheless, the loss of of forage is substantial. Harris and Cranston (1979) put the average loss at $12/ha and the potential annual loss to B.C. and its ranching industry at $13 million if knapweeds spread to their limits.

Containment and Control

A two-pronged response has developed to this very serious problem. The first is a containment program, begun in 1969, to

Knapweed attached to a pickup truck.

limit the spread of knapweeds while a control program, the second "prong", is being developed.

Containment is being sought by spraying with the persistent herbicide Tordon 22K on the periphery of infested zones. Spread is mostly along roads and trails and so spraying is done from four-wheel drive pick-up trucks. There is also some roadside spraying within infested areas so as to reduce the likelihood of knapweed plants or seeds being picked up and transported out of the infested areas.

No satisfactory cultural control except irrigation has emerged, indeed cultivation can provide an ideal invasion site, and so hopes for eventual continuing control are centered on biological agents. Knapweeds are introduced plants and some of their success can be attributed to the absence of natural enemies. Biological control possibilities in B.C. are much the same as those described by Maddox in his companion article, and thirteen releases of the four likely agents of control which he discusses had been made by 1960. Their progress is being carefully monitored.

An important addition to the containment and control program is the development of greater and more widespread public awareness of knapweed, its characteristics, and the processes of its spread. Man's activities, most notably the inadvertent spread of mature knapweed plants on logging trucks, off-road vehicles, and trail bikes (Fig. 3) have contributed greatly to the spread of knapweed. Invasion pathways develop quickly as off-road vehicles scuff up the rangeland surfaces and, with dried plants being carried hither and yon, seed is never far from these sites. Not enough has yet been done to inform the general public or to stimulate people to take simple precautions such as checking their vehicles before leaving a weed-infested area. It was only last year, (1978) for example, that the problem was explained to the B.C. Outdoor Recreation Council and a warning written for their Newsletter. Now there are two annotated slide shows, for lay and professional audiences, but more copies are needed for general distribution. Forceful steps by all agencies concerned are needed to engender public awareness and interest.

Summary

From the time of their introduction about 1900 until now, the knapweeds, *Centaurea* spp., have spread vigorously to occupy at least 30,000 ha and to be present throughout the rangelands of interior B.C.

Reduction of forage production in the presence of knapweed is considerable, up to 90% in some instances, and so control measures are urgently required.

While a biological control program using natural predators introduced from the knapweed's home habitat is being developed, a chemical containment program is in force in an effort to limit spread until biological control is effective. Picloram or Tordon 22K is being sprayed in peripheral areas of infestation to restrict further extension of areas of infestation. Allied to this chemical treatment, a program to generate better public understanding of the problem, its implications, and the role of the public in minimizing spread of knapweed is needed.

References

Fletcher, R.A. 1961. A growth inhibitor found in *Centaurea* spp. M.Sc. Thesis. Dep. Plant Science, Univ. British Columbia.

Fletcher, R.A., and A.J. Renney. 1963. A growth inhibitor found in *Centaurea* spp. Can. J. Plant Sci. 43:475-481.

Harris, P. and R. Cranston. 1979. An economic evaluation of control methods for diffuse and knapweed in western Canada. *In Press.*

Renney, A.J. 1959. *Centaurea* spp. infestations in British Columbia. *Proc. Joint meeting, N. Central Weed Control Conf.* 16 and W. Canada Weed Control Conf. 10:18-19.

Watson, A.K., and A.J. Renney. 1974. The biology of Canadian weeds, *Centaurea* diffusa and *C. maculosa*. Can. J. Plant Sci. 54:687-701.