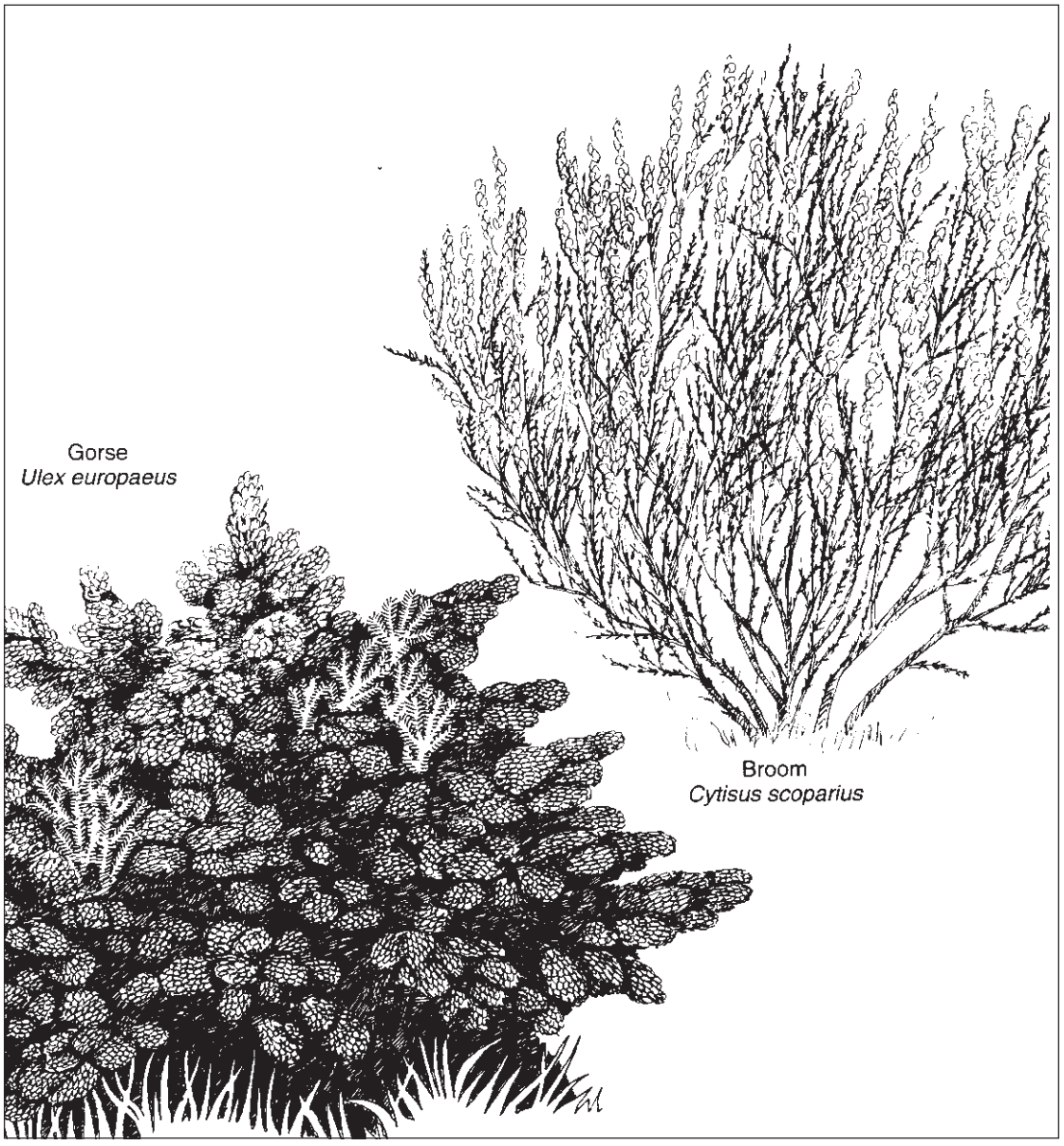
SILVICULTURE

Broom and Gorse in British Columbia

A Forestry Perspective Problem Analysis



Province of British Columbia

Ministry of Forests

Broom and Gorse in British Columbia

A Forestry Perspective Problem Analysis

by

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Executive Summary

Broom, an erect deciduous shrub, and gorse, a similar evergreen shrub with spines, were introduced to British Columbia many years ago. These species have now spread to become competitors with crop trees on some forest sites.

The authors found that broom has become a serious concern in some plantations in the Duncan Forest District on Vancouver Island. Gorse is found in association with broom, primarily as a roadside species in the same area. Broom is perceived as a potential threat to the integrity of several unique ecosystems on southern Vancouver Island, while gorse may be a fire hazard where it is concentrated on dry sites within this area. Broom has also been found on roadsides in the West Kootenays of the British Columbia interior where it appears to be only marginally suited to the more severe climate. These species are not present in significant numbers in other areas of the province.

Both species are aggressive colonizers, able to fix nitrogen and produce prolific seed crops. These seeds can be banked in the soil for decades. Although both species depend on disturbance for establishment and rejuvenation of existing stands, outside British Columbia gorse has shown the potential to capture an entire site for much longer than broom. Due to its spiny nature, extensive gorse cover also has the potential to make a site virtually inaccessible to forestry workers and the public.

Experience in New Zealand, where broom and gorse appear to be much more aggressive, suggests that control of these species can be difficult. The general responses to the range of management treatments are as follows:

Burning

- Broom and gorse re-sprout vigorously from the roots after a burn.
- Burning creates ideal germination and growing conditions.
- Numerous seedlings can develop from banked seed.
- Sprouting is often intentionally encouraged by burning since new sprouts are easier to treat with other methods.

Manual Cutting

- Cutting will stimulate sprouting from the basal portion in young stems of either species.
- Ability to re-sprout appears to be a function of age and season of treatment.
- Established conifers may grow quickly enough, once released from competition, to get above developing sprout.

Mechanical Implements

- Mechanical implements are used to stimulate sprouting from seed or roots to facilitate further treatment.
- They are used to crush broom to the ground to encourage a burn.

Herbicides

- Picloram is very effective in controlling broom and gorse. However, it is not registered in Canada for silvicultural use but is registered for roadside and range use.
- 2,4-D and glyphosate have produced variable results in limited trials in British Columbia, while they have been proven ineffective in New Zealand.
- Hexazinone appears effective on soft-spined gorse at 4–4.5 kg ai/ha using liquid soil applications.
- Triclopyr ester is very effective as a foliar application at 1.5 kg ai/ha or applied to stumps with an oil carrier.
- Herbicides may have to be applied several times to control re-spouting after burning, as well as applied to the germinants that follow.

Grazing

- Sheep have a low preference for broom and gorse sprouts and have shown variable results for control.
- Goats prefer fresh sprouts of these species and can be quite effective in their control.

Alternative Cover Plant Species

- Cover crops like clover and grasses may exclude gorse and broom if sown immediately after site disturbance.
- Competition potential of cover crops should be considered if crop trees are to be established on these disturbed or degraded sites.

Biological Control with Insects

- Both broom and gorse appear to have many more native insect pests in North America than in New Zealand.
- A seed-feeding weevil was introduced to Washington State in the 1950s to control gorse and has caused about 96% reduction in seed production after 30 years.
- It is not known what impact, if any, this weevil has had in British Columbia.
- The Oregon Department of Agriculture is seeking approval for the importation of a mite and a thrips for biological control of gorse.

Broom and gorse represent a significant threat to forested ecosystems in British Columbia because of their competitive abilities and their potential for spreading beyond their current range. Therefore, a strategy to control them on forest land and to curtail their spread is recommended. The top priority will be to control the spread of these species by working with public agencies and private companies that own or administer land which may be or has been affected.

Recommendations are made to conduct an informal, inexpensive inventory and formal research to learn more about distribution, competitive abilities and control of these species. Suggestions are also given for those concerned with control of broom and gorse.

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Introduction

Broom and gorse have long been associated with roadside vegetation in portions of southwestern coastal British Columbia. Recently, forest managers and the public in British Columbia have become concerned about the competitive abilities of broom and gorse. Some people consider the pollen of broom a contributor to hay fever. These species have become increasingly noticeable in newly harvested areas and other disturbed sites on southeastern Vancouver Island. In addition, there is concern that these species may be spreading and could pose a greater threat in the future.

This report investigates the presence of gorse and broom as competing species in British Columbia, their impact on crop trees and other non-timber forest resources, and their control.

The investigation consisted of a literature review of foreign studies (especially from New Zealand) and telephone interviews of British Columbia foresters, biologists and other experts in the field. Experience from elsewhere has been compared to the perceptions and experience of practitioners in British Columbia.

Description

Broom

Broom (or Scotch broom), *Cytisus scoparius*, is an erect, occasionally prostrate, shrub up to 3 m tall with unarmed stems and small leaves. The new slender stem growth is angled and green. Leaves are deciduous, alternate, 1–3 foliate with ovate leaflets (Fig. 1).

Broom has yellow, rarely white, axillary flowers with a purple or brownish tinge. These flowers appear early in the spring, forming long terminal racemes. The flowers mature into dehiscent pods with spiralling valves, containing two, or many more, seeds (Taylor 1974).

The leaves, buds and pods have been recorded as being poisonous, although during pioneering times roasted seeds were used as a coffee substitute and new shoots as a replacement for hops in beer production. The name "Scotch broom" is quite appropriate as it was used in Scotland to make household brooms (Robinson 1979).

Gorse

Gorse, *Ulex europaeus*, is a spiny, somewhat glaucous evergreen shrub up to 2 m tall or taller. The main branches are ascending, greenish and angled with acicular leaves that are generally shorter than the conspicuous spines (Fig. 2).

The terminal flowers are yellow with a velvety pedicel. Flowers of gorse develop into black pods with dark hairs (Taylor 1974).

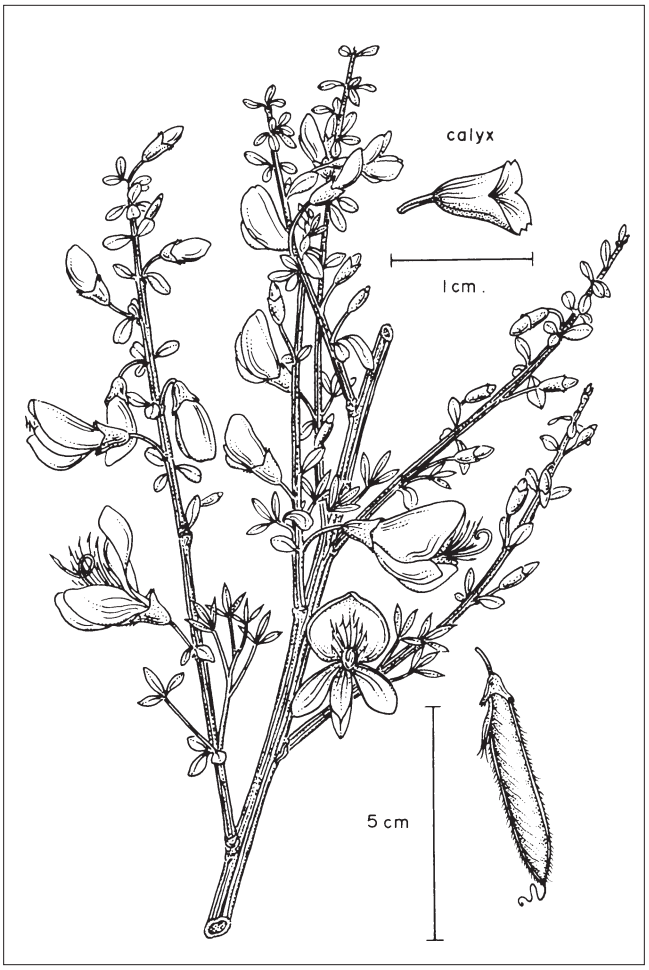

*Figure 1. Broom (*Cytisus scoparius*). Source: Taylor 1974. Courtesy of the Royal British Columbia Museum, Victoria.*

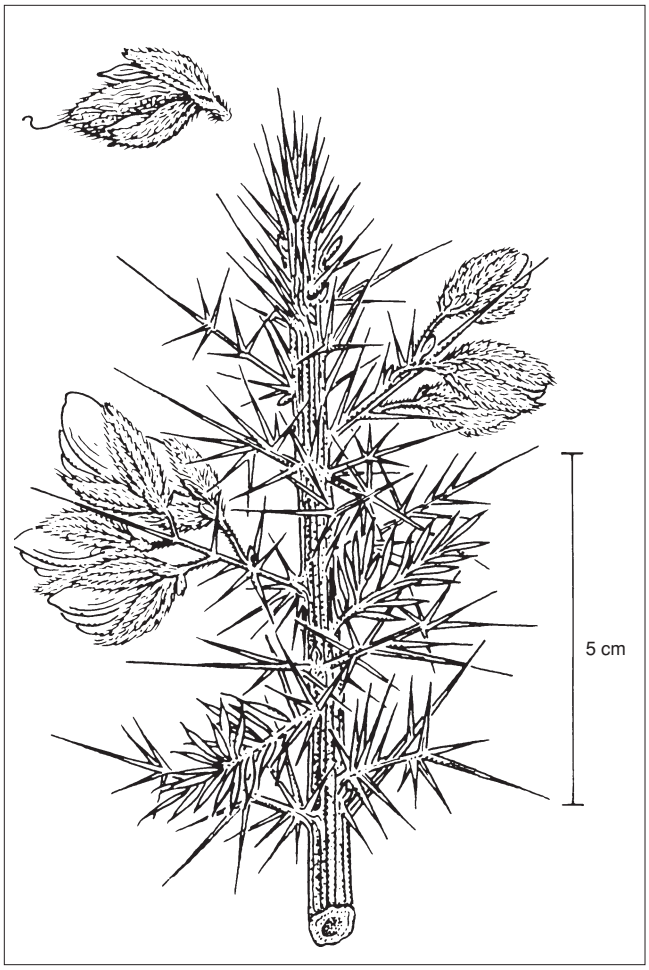

*Figure 2. Gorse (*Ulex europaeus*). Source: Taylor 1974. Courtesy of the Royal British Columbia Museum, Victoria.*

Distribution

Broom

Scotch broom comes from a genus of 50 species which originate in the Mediterranean region of Western Europe. The species spread through much of Europe and Britain hundreds of years ago. Broom has been introduced to New Zealand, the Pacific Northwestern United States and coastal British Columbia as a garden or ornamental hedge species and has since spread far beyond the bounds of cultivation in all locations (Dennis 1980; Syrett 1988).

In British Columbia, the credit for the introduction of broom has been given to Captain Walter C. Grant, the wealthy son of Wellingtons's chief intelligence officer at Waterloo, who travelled to Vancouver Island in search of adventure. Captain Grant apparently secured broom seed during a visit to Hawaii, where it had been recently introduced. Grant broadcast these seeds around his thirty-five acre (14 metric ha) estate at Sooke in the 1850s (Newman 1987).

Since its introduction to British Columbia, broom has become extensively naturalized on southern Vancouver Island, the Lower Mainland and the Gulf Islands (Taylor 1974). Broom occurs along the eastern side of Vancouver Island as far north as Campbell River, with sporadic occurrence further north. It has been reported in the Gulf Islands as far north as Cortes, Hernando, Savary and Texada Islands (Fig. 3).

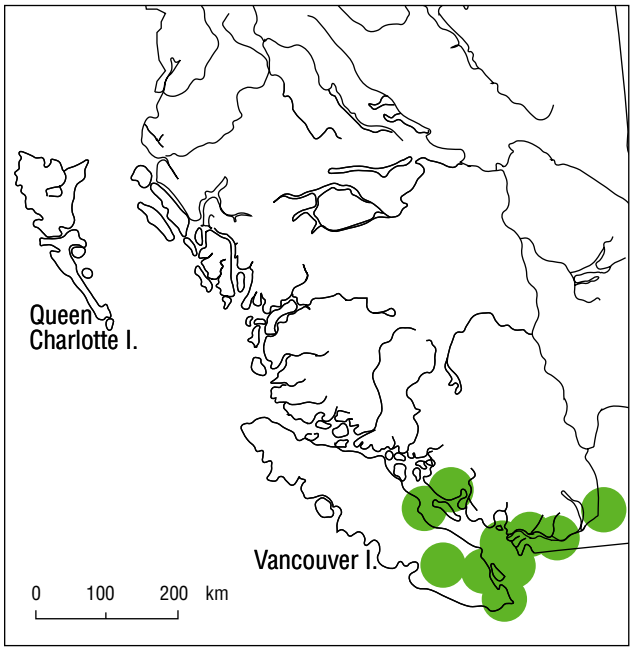

Figure 3. Approximate distribution of broom in British Columbia. Source: Taylor (1974); L. Anderson, B. Fougere, R. Mueller, pers. comm.

Broom can be found on the Lower Mainland, up the Sunshine Coast to Powell River, and through the Fraser Valley, the Chilliwack Valley, and Hope. On the outer fringes of its range, broom tends to be found close to roadsides. However, in the mediterranean climate of the West Vancouver/Squamish area, the Gulf Islands, and southern Vancouver Island, broom can be found extensively on exposed hillsides (L. Anderson, B. Fougere, and R. Mueller, pers. comm.).

Broom has also been introduced to the West Kootenay region in the British Columbia interior, spreading as a roadside species along the north side of the west arm of Kootenay Lake, with sporadic occurrences on the east side of the lake and between Nelson and Castlegar (M. Ketcheson, pers. comm.). Broom can also be found throughout coastal Washington, Oregon and northern California (Miller, 1992a).

The spread of broom on the south coast of British Columbia may have been encouraged in the past by its deliberate use in several B.C. Hydro and Ministry of Transportation and Highways slope stabilization projects on the south coast. Also, the Ministry of Transportation and Highways has avoided mowing or removing broom where it has become established naturally along highways and roads on the south coast. Currently, B.C. Hydro does not intend to use broom for slope stabilization. The Ministry of Transportation and Highways has not used scotch broom for many years and it is now encouraging the removal of broom along roadsides when it becomes unsightly and "leggy." It is also considering the removal of broom from its list of "desirable native species." Even ornamental forms of broom (Warminster, Genista and Creeping broom) that do not reproduce from seed and have been used extensively in highway landscaping are falling out of favour with the public because of their pungent aroma and associated effect on allergies. For this reason the Ministry of Transportation and Highways is favouring native vegetation in its landscaping (B. Hall, B. Nixon, A. Planiden, and W. Smith, pers. comm.).

Gorse

The origin and historical spread of gorse worldwide is similar to that of broom (Taylor 1974). In New Zealand it was introduced by early settlers and sold by seed merchants and nurseries for private cultivation until the 1890s (Lee *et al.* 1986). Since then it has spread to cover more than 3% of the total land area in New Zealand, including significant agricultural areas and forest plantations (Hilgendorf and Calder 1967; Blashchke *et al*. 1981; J. Barker, pers. comm.)

In North America, gorse was first introduced in south coastal Oregon and has infested many areas within this region. Gorse has also spread as far south as San Diego county and north through Washington State into coastal British Columbia. Although gorse infestations in Oregon become less severe in northern

and inland portions of the state, there is great concern that these areas are also very susceptible (Isaacson 1992a).

The distribution of gorse in British Columbia seems to be more constrained than that of broom, being concentrated in the Jordan River–Victoria area on southern Vancouver Island (Fig. 4). In addition, it has spread to South Pender Island, where it can be found carpeting significant areas (Taylor 1974; D. Eastman, and A. Skabeikis, pers. comm.).

While some feel that gorse in British Columbia has not spread much in the last 25 years (R. Mueller, pers. comm.), others feel that it is spreading through an extensive portion of southern Vancouver Island, in disturbed areas near most communities (R. Furness, pers. comm.). In fact, isolated occurrences are reported as far from its known range as North Vancouver, and Sandspit on the Queen Charlotte Islands (R. Furness and M. Scott, pers. comm.).

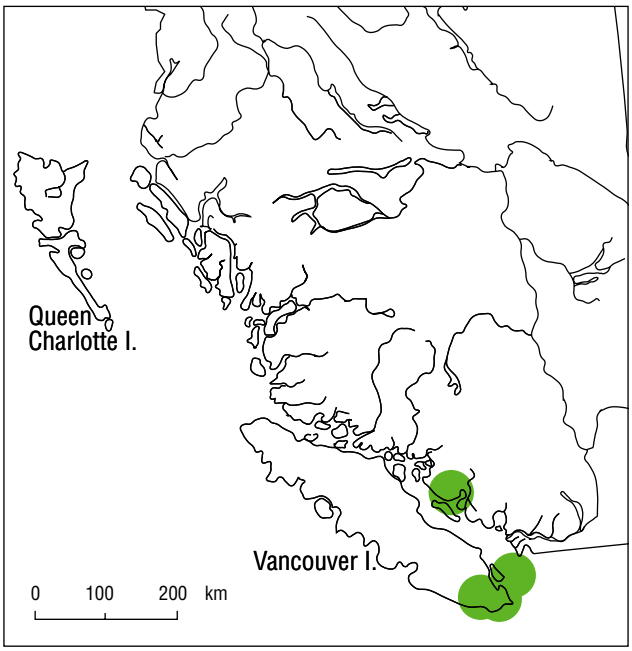

Figure 4. Approximate distribution of gorse in British Columbia. Source: Taylor 1974; L. Anderson, B. Fougere, R. Furness, R. Mueller, pers. comm.

Habitat

Climate

The distribution and habitat of gorse and broom suggest a similar climatic preference. These species are primarily found at lower elevations within the Coastal Douglas-fir (CDF) biogeoclimatic zone and the drier, maritime Coastal Western Hemlock (CWH) subzones. This portion of coastal British Columbia is characterized by a mild, maritime climate, with seasonal (but not terribly severe) summer droughts (Meidinger and Pojar 1991). Although these species range south along the coast to California, expansion of the range upward in elevation or geographically to the north or east may be limited in British Columbia because of the more severe winter environment and severe summer drought (Taylor 1974; Williams 1981; Lee *et al.* 1986).

Broom has only appeared in the British Columbia interior within the West Kootenay region where it can be found mostly as a roadside species on warm, southerly, edaphic exposures in the warm, moist Interior Cedar-Hemlock (ICH) subzone. Even under these mild climatic conditions, considerable dieback has been observed in harsh winters, indicating that the climate is only marginally suited to broom (M. Ketcheson, pers. comm.).

Isolated gorse plants have been discovered as far north on the British Columbia coast as the Queen Charlotte Islands, triggering concern that further expansion of its range along the coast may be possible (M. Scott, pers. comm.).

The extent to which present climatic conditions have limited the range of broom and gorse in British Columbia is not entirely clear. Certainly severe frosts will limit distribution of these species. However, a significant area exists on the British Columbia coast that is climatically suited to these species, while a much smaller, marginally suited area can be found in the West Kootenays of the British Columbia interior. Gorse in particular appears to be well suited to coastal climatic conditions far beyond its present known range.

Site and Soil Conditions

Both broom and gorse compete readily within their respective ranges for well-drained, excessively disturbed areas. Often these sites can be found as roadside or landing disturbances, where soils have been degraded or have an inherently lower productivity (Taylor 1974; R. Furness, pers. comm.).

In New Zealand, broom and gorse dominate extensive river floodplains where floods and fresh alluvium often provide new areas for colonization. In these areas broom tends to dominate freshly disturbed sites, while gorse becomes established on less disturbed sites (Williams 1981).

Nutrient Relations

Broom and gorse are able to survive on a wide range of nutrient regimes (Taylor 1974; Williams 1981). Both have been recognized as efficient nitrogen fixers, capable of fixing up to 200 kg/ha (Engunjobi 1969; Gadgil 1983). In some trials broom was found to have more than double the nitrogen content in its foliage than snowbrush ceanothus and triple the root nodule activity of red alder (Warwick 1983; Helgerson 1984).

Gorse, and to a lesser extent broom, tend to acidify the soil, and accordingly these species are tolerant of strongly acidic conditions (Grubb *et al.* 1969; Williams 1981). The accumulation of litter and the removal of bases, particularly calcium, may be responsible for this acidification (Williams 1983). Although broom and gorse are generally associated with poorer soils, they will respond to increases in phosphorus, boron and molybdenum (Knight 1969; Williams 1981).

Water Relations

Broom and gorse have been described as being well suited to habitats with seasonal moisture stress, although they may not be able to survive severe, extended drought (Williams 1981). Both species have adaptations to cope with a dry environment: a deep taproot; a reduction in leaf surface area; and photosynthetically active stems bearing sunken stomata beneath a thick epidermal wax covering. Broom also has the advantage of being able to abscise its leaves during a drought to conserve moisture (Lee *et al*. 1986; R. Mueller, pers. comm.).

Light Relations

In the mild climate of the Oregon Coast Range, broom will photosynthesize into the winter (Wheeler *et al*. 1979).

Both broom and gorse are moderately shade tolerant. It has been suggested that gorse is slightly more tolerant to shade than broom (Balneaves 1981).

A range of light intensities may have contributed to the wide range of growth forms observed in broom. In greenhouse experiments, young broom plants developed slow vertical growth under full light, with over 50% of total weight allocated to root growth. Conversely, under 30% of full light, young broom was almost three times as tall as full-light plants after only 65 days. However, the shaded plants had no lateral branches and displayed a weakly nodulated root system. Such a contrast in morphological characteristics to deal with varied light conditions has not been observed in gorse (Williams 1981).

Habitat

Temperature Relations

Gorse and broom have a low tolerance to frost (Williams 1981), which could be a major factor influencing their distribution in British Columbia. In the West Kootenays, on the margin of its British Columbia range, broom exhibited major top-kill and die-off from frost and winter desiccation in 1990–91 (M. Ketcheson, pers. comm.).

During the harsh winter of 1990–91 on southern Vancouver Island, R. Furness (pers. comm.) observed that old gorse foliage died back, causing the top section to dominate and giving the gorse a form similar to "leggy" broom.

Reproduction, Growth, and Development

Reproduction from Seed

Both broom and gorse produce large amounts of seed annually, starting at 2–3 years of age. Broom is known to produce 2000 to 3500 seed pods per bush, with up to 9 seeds exploding out of each pod when ripe. Seed dispersal in broom is assisted by this explosion of the pods. Dispersal for broom generally occurs over 15–20 days for an individual bush with the timing dependent on the position of the pods and the relative warmth of air layers (Waloff and Richards 1977; Muenscher 1980; Williams 1981).

It is likely that broom and gorse seeds are dispersed in British Columbia by vehicles, which pick up seed in mud and gravel along roadsides and in gravel pits and distribute it along roads adjacent to forest land. Once a local seed supply is established in this way, other dispersal mechanisms will assist spread when an appropriate seedbed is created (B. Nixon, pers. comm.).

Both broom and gorse seed are readily transported by water, with the hard seed coat providing protection from abrading gravels in streambeds (Williams 1981). Indeed, it is felt by some that water has been a significant dispersal mechanism for gorse in British Columbia, with gorse occurrences noted near the ocean (R. Furness, pers. comm.). Some researchers have speculated that broom is more readily dispersed by birds than gorse since they prefer to alight in the open twiggy crowns of broom rather than the dense spiny crowns of gorse (Williams 1983).

Both broom and gorse are seed-banking species, producing seeds that may remain viable in the soil for up to 30 years. Seeds in New Zealand can generally be found in the top 5–6 cm of soil, and occasionally as deep as 15 cm (Ivens 1978; Zabkiewicz and Gaskin 1978; Williams 1981; Partridge 1989). Virtually all gorse seeds present in a New Zealand soil after clearing were viable and capable of germination under the proper circumstances (Zabkiewicz 1978).

Broom requires a disturbance to provide open, warm, exposed mineral soil for germination. Logging disturbances from road and landing construction and skidding can often provide such a seedbed. Broom and gorse can become well established on disturbed sites when a lack of sufficient moisture and nutrients limits the rapid establishment of aggressive native vegetation. Germination of both gorse and broom may be promoted by fire, as long as the seed source is not entirely destroyed (Ivens 1983; Williams 1983; Partridge 1989).

Vegetative Reproduction

Both broom and gorse will sprout from the stump if damaged or cut. Observations of cultivated scotch broom by the principal author indicate that sprouting potential declines as broom ages, with little or no sprouting in stems over 20 years of age if cut in late spring. Vegetative reproduction may be important for the persistence and expansion of colonies of broom and gorse previously established from seed (Zabkiewicz and Gaskin 1978).

Growth

Height growth of broom and gorse is rapid. In New Zealand, broom may reach 2.5 m in height and 2 cm in diameter after only 2 years (Williams 1981). Gorse will grow at a similar rate in New Zealand where it has made large areas virtually inaccessible due to its spiny stems (Balneaves and Perry 1982; J. Barker, pers. comm.).

Gorse can live up to 30 years in New Zealand, with an average height between 2.5 to 5 m and a maximum height of 7 m. Diameters in New Zealand range between 2 and 10 cm, with occasional older stems greater than 20 cm (Lee *et al*. 1986). At 12 years of age, large "leggy" gorse plants may start to topple over. This toppling phenomenon has been observed in broom as well, in both New Zealand and British Columbia, limiting the life span of wild broom to 10–15 years, although cultivated broom may persist for more than 20 years (Williams 1983; W. Smith, pers. comm.).

Leaf fall in broom usually occurs in late fall in British Columbia; however, if severe drought occurs broom may loose its leaves in midsummer as a strategy to conserve moisture. Although it is an evergreen species, gorse is known to produce more prodigious amounts of litter than broom (Williams 1981; Lee *et al*. 1986).

Successional Development

Both gorse and broom have a very aggressive reproduction strategy. Both species produce many robust, hard seeds that can survive transport in river gravels and will persist in the soil for many years. Photosynthetic tissue in twigs and leaves dispersed throughout the crown make broom well suited to open, early seral habitats. Later seral plants often establish with broom and readily shade it out in the absence of further disturbance (Williams 1983).

It is believed that broom and gorse have been relegated to a narrow, early seral niche as colonizing species on poor sites in spite of a much broader fundamental niche. This is probably due to excessive competition or other interactions with native species on more favourable, moister and richer sites (R. Furness, pers. comm.).

The ability of broom to channel energy into height growth when competing for light allows it to establish

quite well on some sites, despite moderate competition from other species. In fact, it is often found growing in this manner in British Columbia. Rather than competing directly, gorse will tend to exclude other species by establishing itself quickly with a carpet of individuals emerging from banked seed.

Both broom and gorse plants may become top-heavy and topple at 12–15 years. Broom is generally succeeded at this stage by other species unless another disturbance removes competition and allows for germination of banked seed. However, gorse can maintain a presence with scattered individuals for 25 to 30 years. This relative difference in life span and site occupancy is likely due to several factors.

First, gorse is evergreen while broom is leafless after late summer, allowing more light to reach secondary successional species underneath. Second, gorse produces a massive amount of litter that has a relatively low nitrogen concentration compared with the sparse, readily decomposable broom litter. Therefore, gorse litter tends to accumulate and acidify the upper soil horizons more readily than that of broom, excluding germination and establishment of other species (Williams 1983; Lee *et al*. 1986).

To summarize, although gorse and broom are early seral species establishing as colonizers from banked seed after a major disturbance, gorse appears to have a more aggressive strategy and holds a site longer than broom.

Pests

In Europe and North America, large populations of specialized psyllids and aphids are found on broom. The psyllids have not been found in New Zealand, nor have any specialized aphid species (Syrett 1988). With few natural pests, both broom and gorse have been more successful in New Zealand than any other country. In fact, seed production of broom in England was found to be very close to that of New Zealand broom only when the English broom was treated to eradicate insects feeding on the seed (Waloff and Richards 1977; Williams 1981).

It may be that the impact of insects and other pests in British Columbia, combined with other environmental factors, have reduced the competitive ability of broom and gorse in this province compared to New Zealand. However, this suggestion is speculative and should be investigated further.

Impact on Crop Trees and Other Forest Resource Values

Competition with Crop Trees

Broom and gorse are such a problem in agricultural and forested areas in New Zealand that both were declared "noxious weeds" as early as 1926 (Hilgendorf and Calder 1967). Gorse has been known to exclude native vegetation from a site, because of the high density of stems in young stands and the deep, acidic litter in older stands (Lee *et al*. 1986). In British Columbia, broom has been responsible for reductions in plantable area in parts of southern Vancouver Island, while gorse has not yet spread significantly onto forest sites (R. Furness, pers. comm.).

Gorse and broom can be a problem when they establish in conjunction with planted seedlings, since they can quickly overtop crop trees and are difficult to treat without harming the planted trees (R. Furness, pers. comm.). Because gorse and broom can tolerate moderate shading, they will continue to grow under a partial tree canopy (Balneaves 1981). This situation is common with broom on southern Vancouver Island, where crop tree mortality from early competition has resulted in sparsely stocked stands (R. Furness, pers. comm.).

Although broom has been planted in forested areas to improve the nitrogen status of the soils, planting of broom and gorse is now discouraged because these species compete with crop trees (Chinnamani *et al*. 1965; Helgerson 1984). Even in an understory position, gorse and broom may compete with trees for moisture, nutrients and minerals on some sites, causing a wide variation in the growth rates of individual crop trees (Balneaves 1981; R. Furness, pers. comm.). Since gorse and broom are most prevalent on sites in British Columbia already lacking available moisture and nutrients, it is possible that their presence may exacerbate moisture or micronutritional deficiencies, despite their ability to enhance the nitrogen pool. This situation must be assessed on a site-by-site basis.

In a forested understory gorse represents a significant fire risk. In the Hira Forest in New Zealand, fire spread rapidly through a gorse understory to destroy 1000 ha of Forest Service plantations. The dense gorse understory found on South Pender Island may pose a similar fire risk (D. Eastman, pers. comm.). In addition, a gorse understory in a forest plantation may create access difficulties for stand-tending operations, causing a significant increase in overall costs as well as noticeably affecting tree growth (Balneaves 1981).

Effects on Non-timber Forest Resources

Broom and gorse have been regarded as beneficial species for some forest resource uses. In the past, the B.C. Ministry of Transportation and Highways has regarded scotch broom as more of an asset than a liability. This is because the species establishes easily on roadside rock cuts and droughty soils, providing good erosion control and spectacular masses of colour in the early spring (A. Planiden, pers. comm.). Beekeepers in New Zealand regard gorse and broom as a valuable source of pollen, especially in early spring when few other natural pollen sources are available (Hill and Sandrey 1986).

Elk and deer have been observed browsing broom when it was planted with red alder under commercially pre-thinned Douglas-fir in Oregon (Helgerson 1984). Gorse is regarded as an important forage for both cattle and horses in open pastures in southern England (Tubbs 1974).

In New Zealand, gorse is considered the most undesirable scrub weed in domestic rangelands, precluding more desirable and palatable forage. Gorse has infested over 657 000 ha of New Zealand pastures, greatly reducing the grazing potential for cattle and sheep (Krause *et al*. 1988).

In British Columbia, broom is considered a potential threat to maintenance of native biological diversity by precluding the establishment and spread of many rare endemic plant species, particularly those that occur within the unique Garry oak ecosystems in the small Coastal Douglas-fir zone (Nuszdorfer *et al*. 1991).

Response to Disturbance and Management

Burning

In Europe and New Zealand, burning has been noted as an important disturbance mechanism to perpetuate broom and gorse. After a fire, both species may re-sprout from burned stumps within one month. More importantly, both species find ideal conditions on burned sites for germination of seeds banked in the humus and upper soil layers, and for growth (Balneaves 1982; Radcliffe 1982; Lee *et al*. 1986).

Where fire has been excluded in England, gorse is found to become "leggy" and is inclined to die out after 20 years, rather than develop an uneven-age structure which would perpetuate the stand (Tubbs 1974).

Often gorse and broom are burned so that managers may then control the more vulnerable sprouts. However, broom may be more difficult to burn than gorse, because of the lack of fuel concentration. To deal with this problem in New Zealand, broom stands have first been treated mechanically with a large concrete roller to crush the bushes to the ground, creating better fuel loading for burning (Hilgendorf and Calder 1967). Cutting broom may be just as effective with less potential for site degradation.

Manual Cutting

Broom and gorse will re-sprout from the stump when cut, although sprouting potential seems to vary with the age of the plant and the time of year. According to Miller (1992b), older broom regrows little after cutting. Also, re-sprouting is expected to be low when brooms with diameters less than 2.5 cm are cut to the ground level. As well, control of broom by cutting should be done when it is under maximum drought stress. On one operational project on southern Vancouver Island, 2.5 m broom was cut and within 2 years it had sprouted back to 1 m tall. Such re-sprouting may not be a problem if the crop trees can grow sufficiently within this time to reach a dominant position, eventually shading out the broom (R. Furness, pers. comm.).

When gorse occurs in established forest plantations, it is more of a problem to cut than is broom. The dense, multi-stemmed, spiny nature of gorse cover can make access for cutting impossible. Generally, the selectivity of herbicides is poor for gorse. The best option is to eradicate it at the site preparation stage, before planting (Balneaves 1981; J. Barker, pers. comm.).

Large Mechanical Implements

Since mechanical disturbance or fire generally favours gorse or broom, it would seem that the use of large machinery should not be recommended. However, large equipment can be useful in some very specific situations.

In New Zealand, large mechanical crushers have been used to prepare broom for burning and to provide access for pruners in pine stands with a dense gorse understory. In British Columbia, the B.C. Ministry of Forests in Duncan, Vancouver Island, is planning a trial using the "Justco Brush Hog" to cut broom and gorse in established plantations. With two hydraulically powered, front-mounted cutting wheels, this machine cuts and crushes the bushes to the ground within a 2 m swath between planted trees, providing low ground pressure on a rubber track (J. Barker, pers. comm.; R. Mueller, pers. comm.).

Herbicides

The re-sprouting nature of gorse and broom, and the barriers to access created by mature gorse, have made chemical options popular for control in New Zealand. Twenty years ago heavy doses of picloram or 2,4,5-T were favoured in New Zealand. Indeed, 2,4,5-T is reported to be the most widely used herbicide to control gorse and broom, either applied as a foliar spray or on the stump, often with diesel oil as a carrier (Hilgendorf and Calder 1967; Balneaves and Perry 1982; Hartley and Popay 1982a; Rolston and Devantier 1983; Hartley and Popay 1982b). Since 2,4,5-T is not permitted for use in British Columbia, other herbicides must be examined if chemical options are to be considered.

Picloram

Picloram (Tordon®) pellets have been used successfully by Western Forest Products Limited to control roadside gorse near Sooke, British Columbia (J. Barker and G. Skabeikis, pers. comm.). However, Tordon® is only registered for roadside rights-of-way and rangelands and it is not selective, usually causing damage to crop trees as well.

2,4-D

2,4-D amine (Forestamine®, Guardsman®) has been used on broom and gorse with variable results. However, the ester formulations of 2,4-D (at 3.36 kg ai/ha) have been reported to provide 90% control of broom in Oregon (Miller 1992c). In New Zealand, 2,4-D is usually combined with another herbicide such as picloram or dicamba to make it effective in controlling broom and gorse. Combinations of 2,4-D and other herbicides have also been tried with success in Oregon. About 92% control was obtained with either 2,4-D and triclopyr ester (0.84 + 1.68 kg ai/ha) or 2,4-D and picloram (2.24 + 0.28 kg ai/ha) (Miller 1992c). Observations on Vancouver Island of backyard applications on fresh broom sprouts from stumps have indicated good control if 2,4-D is applied directly after flowering (R. Mueller, pers. comm.). Further tests with 2,4-D in British Columbia are necessary.

Glyphosate

Generally, glyphosate (Vision®) has been proven to be ineffective for control in New Zealand for all applications unless it is mixed with another herbicide such as picloram (Hartley and Popay 1982a; Rolston and Devantier 1983). Glyphosate has been used in New Zealand to top-kill gorse, preparing it for burning. Glyphosate has been tested in British Columbia on mature broom with inconsistent results. However, it may be effective on new sprouts from cut stumps R. Mueller, pers. comm.). Further tests with glyphosate in British Columbia are necessary to establish its efficacy.

Hexazinone

Hexazinone (Velpar®) has shown some favourable results in New Zealand. It controlled gorse seedlings in a root uptake greenhouse study, and in the field on new shoots at 4–4.5 kg ai/ha applied as a liquid to the soil (Porter 1979; Zabkiezicz 1979; Preest 1980). However, control by foliar applications has generally been poor (Porter 1979).

Triclopyr

Triclopyr ester, as Release® (Garlon 4® in the United States), has recently been registered in Canada for forestry. In the United States, application of triclopyr ester at 1.7 kg ai/ha resulted in 90% control of broom (Miller 1992c). Triclopyr has also shown very good results as a foliar application on gorse in New Zealand, even at rates as low as 1.5 kg ai/ha (Rolston and Devantier 1983; Hartley and Popay 1982b). Applications with an oil carrier to freshly cut gorse stumps proved very effective at any time of the year (Hartley and Popay 1982a). Triclopyr controlled mature broom in France at 0.96 kg/ha, applied in autumn or before budbreak in the spring (Michaud 1986).

Other herbicides

Some other herbicides, which have not been registered for use in Canada, have been tried on broom and gorse in New Zealand. Metsulfuron showed good results on soft gorse in midsummer when applied at rates of 0.3 kg ai/ha (Davenhill and Preest 1986). Fluroxypyr gave excellent control of broom in a *Pinus nigra* plantation (Thompson 1988).

Timing for treating broom and gorse with herbicides

Treatment of broom and gorse can be very difficult and costly once crop trees are established. Therefore it is recommended that these species (gorse in particular) be controlled before trees are planted.

The New Zealand Forest Research Institute has developed an effective pre-planting regime to deal with broom and gorse that involves burning the brushfield to encourage new sprouts, followed by a herbicide application in early summer. Broom may have to be crushed or top-killed with a spray before burning to get adequate ignition. Sprouts are sprayed before they are 3 months old and have developed a protective waxy cuticle.

After spraying the sprouting plants, the ground is ripped, encouraging most banked seed to germinate and sprout. The area receives a second herbicide treatment to kill the second wave of sprouts from the seedbank. Areas that receive only one herbicide treatment after burning may have impenetrable gorse over 1 m tall within 5 years of treatment, while only scattered stunted individuals may be present in plantations sprayed twice (Balneaves 1981).

Where other vegetation, such as bracken fern, also re-sprouts after a burn and develops quickly to overtop new gorse or broom shoots, herbicide spray intended for the broom or gorse may be intercepted by this overtopping vegetation. This situation may require a treatment of the overtopping vegetation first or a single treatment of a soil-active herbicide that will control all competing species (Balneaves and Perry 1982).

Grazing

Although gorse has been grazed domestically by horses and cows in England, most attention for control by grazing has focused on sheep and goats (Tubbs 1974). In New Zealand, sheep have been found to be effective although they have a low preference for gorse. If the sheep are quite hungry and the gorse is grazed hard by many sheep for a few days, gorse can be controlled effectively (Hartley 1982). Goats, which show a preference for gorse, have been used successfully in New Zealand, significantly reducing re-growth after burning and encouraging less competitive plants (Radcliffe 1982; Krause *et al*. 1988).

On southern Vancouver Island, both sheep and goats have been used to control broom. While the sheep would not eat broom, good control of broom and salal (*Gaultheria shallon*) was attained with La Manchia goats on a small project in the Duncan Forest District (D. Eastman, pers. comm.).

Alternative Cover Species

In New Zealand, grass-seeding of heavily disturbed soil was successful in severely inhibiting the establishment of gorse and broom seedlings (Balneaves 1982; Ivens 1982). Trials in Spain to replace a gorse understory with a mixture of clover and pasture grasses in a pine plantation were also successful (Pineiro and Perez 1988). Seeding such alternative species may be desirable where exclusion of broom and gorse is the primary objective, otherwise the potential competition of the cover species with crop trees should be considered.

Use of low-growing clover may be considered to minimize impacts on crop trees. On trials in west central British Columbia, lodgepole pine plantations

seeded with alsike clover showed significant improvement in growth and foliar nitrogen concentration in the fourth growing season, once the pine was well above the clover[1]. The B.C. Ministry of Transportation and Highways has hydroseeded some areas in the Vancouver Island Region (near Langford and on South Pender Island) with a clover/grass mixture to control gorse, with variable results (B. Nixon, pers. comm.). Further study of such methods in British Columbia would be worthwhile, considering successes elsewhere.

Biological Control with Insects

New Zealand foresters have been interested in biological control, as gorse and broom have few insect pests there compared to Europe and North America. A public opinion poll in New Zealand suggested that a biological control program, using the combined impacts of goats and imported insects, would be quite popular (Hill and Sandrey 1986).

In the Pacific Northwestern United States *Exapion ulicis*, a seed-feeding weevil, was introduced from France in the 1950s to biologically control gorse. The weevil was tested between 1948 and 1953 to ensure its desirability as a control agent in the United States. It was approved for use there in 1953, released in California the same year, and in Oregon in 1956 (Isaacson 1992c). This insect is now widely distributed in all areas of Oregon and Washington where gorse is well established. In Washington State, up to 96% reduction in seed production was found on some sites after 30 years. The attack on seeds starts in early spring when the female adult insects lay eggs on young gorse pods. The insect larvae feed on the developing seeds inside the pods (Isaacson 1992c). Although the weevil will not kill existing gorse, it appears effective in slowing its rate of spread into new areas (Julien 1987; Isaacson 1992b, 1992c). It is not known if this insect has migrated into British Columbia and affected gorse there.

Studies by the New Zealand Department of Scientific and Industrial Research (DSIR) have recently been completed on *Tetranychus lintearius*, a mite which colonizes gorse plants. The Oregon Department of Agriculture (ODA) is working with the DSIR and the United States Department of Agriculture (USDA) to import this mite to the United States (Isaacson 1992b).

Both Hawaii and New Zealand have recently imported a thrips, *Sericothrips staphylinus,* which attacks the foliage of gorse. The ODA has also shown interest in this insect. An application by the ODA to the USDA plant inspection committee in 1990 for importation of a shoot tip moth (*Agonopterix ulicetella*), which also preys on gorse, was rejected because of concern that some native lupines might also be susceptible hosts (Isaacson 1992b). To date, little work has been done in British Columbia on biological control mechanisms for gorse or broom.

[1] Trowbridge, R. and R.B. Holl. 1991. Effects of alsike clover on early growth of lodgepole pine in west central British Columbia. Unpubl. draft.

Conclusions

Broom has existed in British Columbia for at least 100 years, spreading to become a common species on roadsides and disturbed dry sites in the warm dry regions of the southern coast and to a lesser extent in the West Kootenays. Because of the length of time broom has been in British Columbia it is generally assumed that it has reached the limits of its range. Within the southern portion of its British Columbia range, broom has become a serious competitor with crop trees on dry disturbed forest sites. Most managers who have encountered broom in their operations in this region are concerned about its costly control. However, some of these managers regard gorse as a greater potential threat over the long term.

Gorse was introduced to British Columbia about 20–40 years ago. Although its present range is small, there is concern that it has not achieved its limits for distribution. Moreover, it is a more aggressive species than broom in New Zealand, Oregon and other areas where it has a significant presence. Gorse tends to capture entire sites quickly through banked seed and will occupy sites longer than broom (up to 30 years), precluding establishment of other species. Control of gorse is usually more difficult and costly than of broom.

Over the short term, broom will not likely spread to become a significant forest competitor outside its present limited range. However, harvesting of second-growth timber within this range will likely increase, providing more opportunities for the proliferation of broom (and perhaps gorse) in these disturbed areas.

In southern Oregon where gorse was first introduced, managers recognize the adaptability of this species and its potential for spread. Most control efforts in this state are aimed at preventing the spread of gorse to non-infested northern and inland counties (Isaacson 1992a).

In British Columbia there is a lack of consensus regarding the potential spread of gorse. We do know that only a few scattered sites have severe infestations. However, the species has shown an extensive presence in numerous locations close to roads and towns within its known range and has been spotted considerable distances outside of this range.

It is clear that a better understanding of the distribution and rate of spread of gorse is necessary before it can be adequately assessed as a potential threat to forest land in the short term. In the long run, a shift in climate (temperature rise and drop in moisture levels) on the British Columbia coast would be expected to favour the spread of broom and gorse.

The concern over the present distribution and spread of broom and gorse goes beyond timber management objectives. Both may pose a threat to the maintenance of viable populations of rare plant species on the south coast and to the integrity of the ecosystems where these species are found. If there is a potential for further spread of broom and gorse outside of their known range, this threat will also increase.

Recommendations

It does not appear that control of gorse and broom in British Columbia will be as difficult or as costly as it is at present in New Zealand, as both species have a smaller distribution on forested sites and seem to be less aggressive. However, the magnitude of the problem created by these species in New Zealand, Oregon and elsewhere, and the difficulty and expense involved in control efforts would suggest that these species are significant threats in both a biological or economic sense. Though the short-term risk from these species (particularly gorse) may currently appear to be low, they represent a considerable hazard to forest management objectives if a severe infestation occurs. Also, the long-term risk from these species must be more carefully assessed in British Columbia.

Efforts should immediately be directed toward a better understanding of the distribution and rate of spread of broom and gorse. Management activities should be undertaken to prevent further spread. This should include a coordinated effort with a number of government agencies and Crown corporations, as well as some public education. It is conceivable that, with cooperation and public support, these species can be controlled and direct costs to the B.C. Ministry of Forests and Forest Licensees can be reduced.

We recommend that the following steps be taken to deal with broom and gorse:

1. *Determine the actual distribution and the range of favourable ecosystems for both broom and gorse.* The distribution and habitat information can be gathered relatively inexpensively by directing forestry personnel in appropriate Forest Districts to record and report sightings of broom and gorse, particularly when they occur outside their known range. Information on abundance, growth, form, and habitat would also be useful. Such an inventory should be monitored, with summary reports compiled at 5–10 year intervals.

2. *For each species, formal research should be funded to investigate:*
   a. The rate of spread over the last several decades.
   b. Growth rates and reproductive success in British Columbia.
   c. Impacts on rare, threatened or endangered species, populations and ecosystems.
   d. Impact on moisture and nutrient status. As broom fixes substantial quantities of nitrogen, it may be useful on some sites to improve nutrition. However, there are some concerns regarding impact on micronutrients and competition for moisture. These influences should be studied over a range of sites.
   e. Interactions with insects and diseases currently found in British Columbia.
   f. The full range of treatment options for effectiveness at various stages in the plant's life. Both evaluation and demonstration of these options should be emphasized. Manual cutting treatments, grazing, and various herbicide options (focusing on glyphosate and triclopyr) should be investigated through both formal research and operational trials.
   g. Potential future risks associated with predicted climatic trends.

3. *British Columbia should be in close contact with the Oregon Department of Agriculture regarding its work on biological control agents.* Importation of some of these insects may be considered, depending on the results of the inventories and research suggested above.

4. *After conducting the inventories and research suggested above, consideration should be given to development of a general management strategy for each species in British Columbia.* The strategy will probably have to be aimed at control rather than eradication because of prohibitive costs, site degradation, and other social/economic considerations. This strategy may include distribution of information to the public.

5. *Develop an interim strategy with B.C. Hydro, the B.C. Ministry of Transportation and Highways, the railway companies, and other organizations controlling significant areas of land within the range of broom and gorse.* This strategy should be aimed at preventing further spread of broom and gorse into forested ecosystems by focusing on:
   a. Minimizing excessive soil disturbance during harvesting and other activities on warm, dry, sandy and/or gravelly sites on southern Vancouver Island or the Gulf Islands. As linear vectors for dispersal, roadsides should receive considerable attention. For timber harvesting sites, plans for disturbance reduction should be incorporated into the Pre-Harvest Silviculture Prescription (PHSP).
   b. Immediate seeding of alternative cover crops in areas where unavoidable disturbance occurs. A low-growing nitrogen fixer, such as alsike clover, should be favoured to minimize competition if crop trees are to be established. Even if these areas cannot support trees at present, the exclusion of broom and gorse may justify the treatment.

6. *Incorporate broom and gorse considerations and options into appropriate training programs for land managers within the range of these species.*

Recommendations

7. *If broom or gorse is currently a problem on forested sites where managers wish to control these species, the following treatments should be considered:*
   a. Where gorse or broom are present before planting, use large mechanical cutters or choppers and fire to remove mature broom and gorse and to encourage new sprouts near ground level.
   b. Where broom and gorse exist in a plantation, cut or crush the bushes manually or mechanically to encourage new sprouts near ground level.
   c. Treatments "a" or "b" should be followed by:
      - grazing by goats (within 3 months). Planting should follow once the vigour of the broom and gorse has been significantly reduced, or
      - an application of hexazinone or triclopyr.

NOTE: Grazing or herbicide treatments may have to be repeated to treat sprouts from cut stems and sprouts from banked seed in the soil.

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