# Review

## The Biology of Australian Weeds 28. *Cytisus scoparius* (L.) Link subsp. *scoparius*

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### Name

*Cytisus scoparius* (L.) Link subsp. *scoparius* (Fabaceae).

Standard common name: broom (Lazarides and Hince 1993). This name is used throughout the present paper except where nomenclature or taxonomy is discussed. Other common names applied to this plant in Australia include Scotch broom, English broom, common broom and Spanish broom (Hartley 1979).

*Cytisus* is derived from the Greek 'kytisos', the ancient vernacular name for a closely related clover-like fodder plant found on the Greek island Kithira; *scoparius* is Latin and means 'broom-like', referring to the numerous erect twigs.

*Sarothamnus scoparius* (L.) Wimmer has been used in much of the older literature, and in some regional floras, but arguments used to separate *Sarothamnus* from *Cytisus* are no longer accepted.

### Description

Broom is an unarmed leguminous shrub, having several erect or ascendant stems which later collapse to become prostrate. Plants grow to 4 m high, and often form dense thickets in cooler areas. Branches are green, five-angled and mostly glabrous. Leaves are usually three-foliate, petiolate to subsessile, but one-foliate and sessile on young growth. Leaflets are narrow-elliptic to obovate, 5–20 mm long and 1.5–8 mm wide, with scattered hairs on the upper surface and numerous short hairs on the lower surface. Flowers are pedicellate, solitary or in pairs, and borne in the axils on 1 year-old stems. The calyx is glabrous, approximately 6 mm long, two-lipped, upper lip with two teeth, lower lip with three teeth, all teeth usually much shorter than the lips. The corolla is golden yellow, 15–25 mm long. Fully developed pods are 2.5–7 cm long and 8–13 mm wide, oblong, dehiscent, strongly compressed, with brown or white hairs on the margin, otherwise glabrous, initially green, black at maturity.

Plants are deciduous in winter in colder areas and in summer in areas with summer drought.

The basic chromosome number of *C. scoparius* is 23 ($2n=46$) (Tutin *et al.* 1968). The chromosome status of Australian material is not known.

The plant is most easily distinguished from other closely related species in Australia by its five-sided green stems, its yellow pea-like flowers, and pea-like pods mainly 2.5–7 cm long with hairy margins (Figure 1). In the field, broom plants are conspicuous because of their dark green colour, and especially their abundant yellow (or occasionally, in hybrids, red and yellow) flowers at peak flowering.

#### *Taxonomy and related species in Australia*

*Cytisus scoparius* subsp. *scoparius* is the most common of the two infraspecific taxa (Tutin *et al.* 1968) and belongs to the *Cytisus* group of the *Cytisus-Genista* complex within the subtribe Genistineae of the tribe Genisteae (Bisby 1981) in the family Fabaceae. There are no native Australian species within this tribe. Two other species within the *Cytisus* group are also naturalized in Australia. Tagasaste, *Chamaecytisus palmensis* (Christ) Bisby & Nicholls, which is promoted as a fodder plant, particularly in Western Australia, (Oldham *et al.* 1991, McGowan and Mathews 1992, Maughan and Wiley 1994), is widely naturalized (Hnatiuk 1990) and is considered to be an environmental weed (Carr *et al.* 1992). *Cytisus multiflorus* (Aiton) Sweet is naturalized in the Creswick area in Victoria (herbarium specimens) and is also considered to be an environmental weed (Carr *et al.* 1992). *C. scoparius* is the only *Cytisus* declared noxious in Australia (Parsons and Cuthbertson 1992).

Several other species within the tribe Genisteae are weeds in Australia. Four species have been declared noxious, *Calicotome spinosa* Link (often the generic name is listed incorrectly as *Calycotome*), *Genista linifolia* L. (*Teline linifolia* (L.) Webb & Berth), *G. monspessulana* (L.) L. Johnson (*T. monspessulana* (L.) C. Koch) and *Ulex europaeus* L. (Parsons and Cuthbertson 1992). Four other *Genista* species are also considered to be naturalized in Australia, *G. canariensis* L., *G. horrida* (Vahl) DC., *G. monosperma* (L.) Lam. and *G. stenopetala* Webb & Berth. (=*G. maderensis* (Webb & Berth.) Lowe misapplied, *T. stenopetala* Webb & Berth) (Hnatiuk 1990, Gardner 1991). All of the noxious weeds and *G. stenopetala* are problems in various parts of Australia (Auld and Medd 1987, Parsons and Cuthbertson 1992). Apart from *C. scoparius* the major weeds in this group are *G. monspessulana* and *U. europaeus*. *Genista monspessulana* is frequently misidentified as *C. scoparius* and vice versa. *Genista monspessulana* can readily be distinguished as it has ridged (but not five-sided) stems, flowers 0.8–1.3 cm long and densely hairy pods mainly 1.5–2.5 cm long (Figure 2).

### History

The exact date of the initial introduction of broom into Australia is unclear. It apparently took place about 1800 after Governor King requested broom seeds which were to be grown and used as a substitute for hops (Waterhouse 1988). Later introductions were made for ornamental

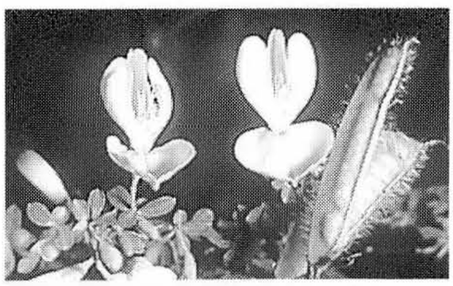

**Figure 1. Flowers and pods of *Cytisus scoparius*, note that pods of this species have hairs only along the pod margin.**

**Figure 2. Flowers and pods of *Genista monspessulana*, note that this species has densely hairy pods.**

**Figure 3. Distribution of *Cytisus scoparius* in Australia.**

purposes and several cultivars and hybrids can still be purchased from garden nurseries.

Broom was considered naturalized in Victoria in 1887 and by 1901 was enough of a problem to be declared noxious (Parsons and Cuthbertson 1992). The earliest herbarium record for New South Wales is for a specimen collected from Braidwood in 1891, unfortunately, without information on whether the species was considered to be naturalized or not. Broom is a common weed in this area today. At Barrington Tops the first individuals were reported to have been planted in the 1840s, and it was recognised as a widespread problem there by 1961 (W.R. Epps personal communication).

## Distribution

*World*

Broom is native to Europe, from Ireland to west central Ukraine and from southern Spain to southern Sweden and also to the Azores (Tutin *et al.* 1968). It has become a weed of temperate areas of the western USA, Hawaii, Canada (British Columbia), New Zealand, south-eastern Australia, India, Iran and South Africa (Parsons and Cuthbertson 1992).

*Australia*

Parsons and Cuthbertson (1992) give a partial distribution of broom in Australia. Current distribution based on herbarium records, knowledge of the authors and those involved with its control is shown in Figure 3.

The largest infestation of broom in Australia now occupies about 10 000 ha at Barrington Tops, New South Wales (Waterhouse 1988). Broom is also considered to pose a serious threat to the Australian alps national parks (Fallavollita and Norris 1992). Other large infestations occur in the Central and Southern Tablelands of New South Wales, the Adelaide Hills and higher rainfall areas in Victoria and Tasmania. Estimates of the area infested in various Australian states are 20 000 ha in New South Wales (J. Hosking unpublished data), 150 000 ha in Victoria (Lane *et al.* 1980), 33 000 ha for the west coast region of Tasmania (A. Barnes personal communication) and 3710 ha in South Australia (provided by Animal and Plant Control Commission, Primary Industries, South Australia in 1991).

## Habitat

*Climatic requirements*

Broom occurs mainly in cool temperate areas of Australia. In Victoria and Tasmania it may be found down to sea level, but in New South Wales most of these areas are over 600 m above sea level. Broom seedlings may die in sunny situations during rainless periods, even in the cool and humid environment of Barrington Tops plateau. In drier climates broom is restricted to the edge of watercourses and along drainage lines.

*Substratum*

In its native range broom is usually a calcifuge (Clapham *et al.* 1962, Tutin *et al.* 1968). In Australia, broom occurs on soils derived from a wide variety of substrates, particularly basalt. It grows best on moist, fertile soils and is rarely found on undisturbed skeletal sandy soils. Although the species is found in Sydney sandstone country in the Blue Mountains, it is largely confined to drainage lines and disturbed areas.

*Plant associations*

Broom is found in grassland and woodland/open-forest (Figure 4), including a wide range of disturbed as well as undisturbed communities. Plants establish best after soil or vegetation disturbance, such as fire and herbicide treatment. However,

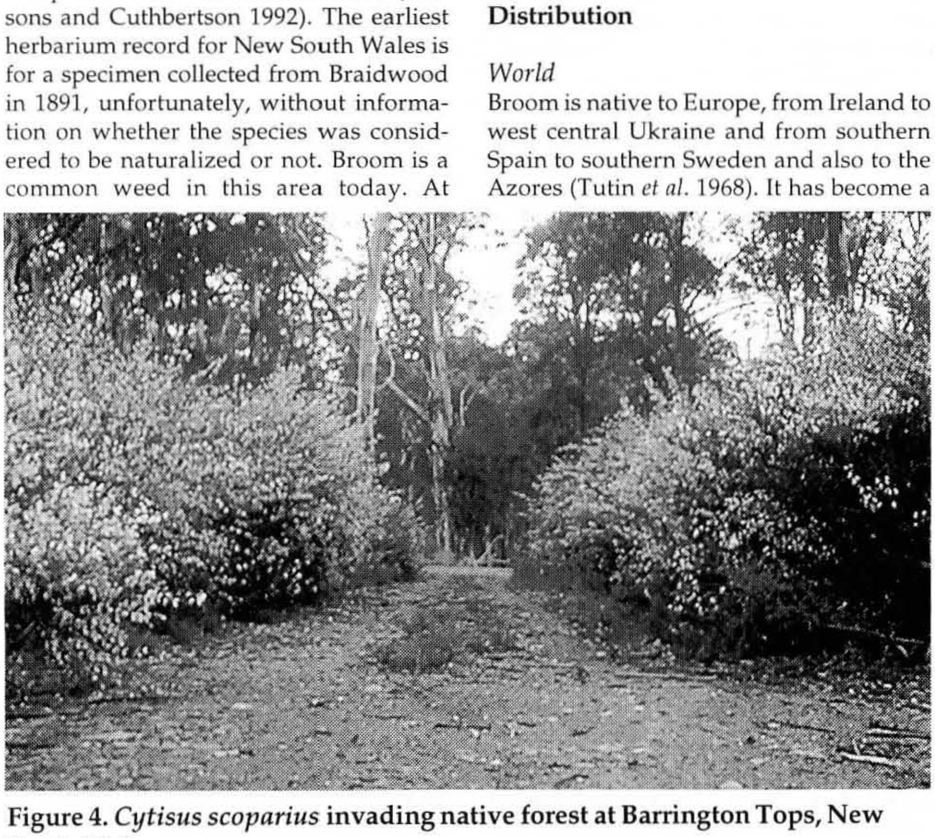

**Figure 4. *Cytisus scoparius* invading native forest at Barrington Tops, New South Wales.**

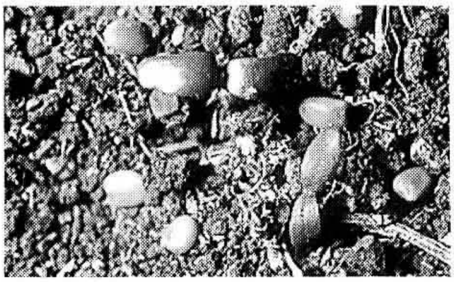

**Figure 5. Seedlings and seeds of *Cytisus scoparius*. Seedlings that emerge in areas shaded by dense *C. scoparius* fail to survive.**

broom can readily invade vegetation without major disturbance, with seedlings being found in open microsites such as along wallaby tracks. Broom can invade eucalypt-dominated vegetation where the tree foliage projective cover is less than about 50%, where it typically forms dense, continuous thickets (Waterhouse 1988). Successful seedling establishment takes place away from broom canopy shading (Figure 5), usually in disturbed patches such as animal tracks, pig-dug areas and beside fallen timber. Broom also invades and persists in treeless vegetation such as subalpine grassland and cleared pastureland. In open areas, tussock grasses provide the drought/grazing protection necessary for establishment. It will not grow in heavily shaded or swampy places (except on drier islands).

Microclimate is altered significantly under broom thickets, with conditions becoming shaded and more humid. This leads to a more mesic understorey developing, with an absence of regeneration by light-demanding trees such as eucalypts, and invasion by new faunal elements (Smith 1994a).

## Growth and development

### *Physiology*

Photosynthesis occurs through the green stems and leaves. Young stems remain green for about three years. At six sites at Barrington Tops, green stems comprised 13–27% of total fresh live stem biomass in 1992, and 15–27 % in 1995. Live stem biomass from two of these sites was oven-dried. Dry weights were 1.41 and 2.63 kg $m^{-2}$ in 1992 and 0.26 and 1.34 kg $m^{-2}$ in 1995, these values being 46–51 % of fresh weights (J.M.B. Smith unpublished data). Stem photosynthetic tissue has been shown to contribute approximately 40% of photosynthates in this species (Bossard and Rejmanek 1992). Leaves are shed in periods of stress such as dry periods in summer, and in cold areas in winter or toward the end of the growing season in autumn. Broom is intolerant of shade; seedlings usually die if germination occurs beneath parental or other relatively dense canopy cover.

Rhizobial nodules on broom roots fix nitrogen (Allen and Allen 1981), but compared to agricultural legumes, broom is relatively poorly nodulated and has low nitrogenase activity (Wheeler *et al.* 1979). Nevertheless, this is probably important in allowing broom to grow on nitrogen-poor soils (Williams 1981).

### *Phenology*

Germination occurs mainly in the spring and autumn, and the relative importance of these two germination periods varies from year to year. In drier areas, spring seedlings rarely survive the summer unless protected by surrounding vegetation (A. Sheppard and P. Hodge unpublished data).

Broom plants generally flower first in their third year (Smith and Harlen 1991). While flowers can be found on plants at any time of the year in warmer climates, most flowering occurs from October to December in Australia (Parsons and Cuthbertson 1992) and New Zealand (Williams 1981). At Barrington Tops, flowering begins in late October at lower altitudes and late November at higher sites, reaches a peak after a few weeks and continues at declining levels until May. Seeds are mostly shed from January to early March.

## Reproduction

### *Seed production and dispersal*

Only a small proportion of broom flowers develop into fruits (Smith and Harlen 1991), although this is known to vary from plant to plant and between patches (Waloff and Richards 1977). A biennial cycle of relatively low and high pod density has been observed (Waloff and Richards 1977). The proportion developing at Barrington Tops varied between 1.7 and 8.2% in two consecutive years (Smith and Harlen 1991). Fruits ripen over summer, releasing seeds explosively on sunny days when pods develop torsional stresses as they dry out. Seeds are released from late December onwards. Seed fall can be quite extended, the last seeds being released in winter. Seed production at Barrington Tops under a broom canopy with a *Eucalyptus* overstorey was 28–356 seeds $m^{-2}$, with considerable year-to-year variability (Smith and Harlen 1991). Seed production under broom canopies beneath and outside a *Eucalyptus* overstorey on the edge of Deua National Park, New South Wales, was 107 and 8885 seeds $m^{-2}$ respectively (A. Sheppard and P. Hodge unpublished data). Pods contain up to 22 green to yellowish brown seeds, although over 99% of pods have fewer than 15 seeds (Smith and Harlen 1991). Mean number of seeds per pod varies from 5 to 8 between sites (Smith and Harlen 1991, A. Sheppard and P. Hodge unpublished data) and from 4.2–11.9 between bushes (A. Sheppard and P. Hodge unpublished data). Seed production per plant has not been recorded in Australia although 2200 pods per plant and 9650 seeds per plant have been recorded elsewhere outside the native range (Paynter *et al.* in press).

Most seed falls within 1 m of parent plants, although exceptionally dehiscence can fling them 4.5 m (Smith and Harlen 1991, Paynter *et al.* in press). Some secondary local dispersal may be achieved by ants (Smith and Harlen 1991, Bossard 1991). Ant dispersal in Australia has only been measured for short distances, up to 1 m (Smith and Harlen 1991). Longer distance dispersal may occur by movement of seed in mud attached to vehicles, machinery, footwear and animals; internally by animals such as horses; or by streams in flood which carry the non-buoyant seeds by bedload saltation (Smith and Harlen 1991).

### *Seed longevity, dormancy and germination*

Like many legumes *C. scoparius* is hard seeded and only a small proportion of seeds germinate at any time. Studies carried out in California showed that fresh seed was 98% viable but that >65% of seeds had an impervious coat that delayed germination for months or years (Bossard 1993). The same study found that about 7% of seed remained ungerminated after three years at 4 cm below the soil surface. In Australia, 69-83% of seeds displayed dormancy in an experiment using seeds collected at Barrington Tops, but dormancy was broken if seeds were treated with boiling water or were scarified (Smith and Harlen 1991). Seeds imbibe water and swell to three times their original size before germination. However not all imbibed seeds germinate, some returning to original size and remaining dormant.

Turner (1934) found that four of 636 broom seeds were viable after 81 years of dry storage. More than 80% of seeds buried in nylon mesh bags at Barrington Tops were still alive and dormant after more than 45 months; viability was also retained for similar periods by seeds stored under water (Smith and Harlen 1991).

Seed longevity contributes to large soil seed banks below broom in the native and introduced range. In the native range soil seed banks below a mature broom canopy have been found to vary from 430 to over 10 000 $m^{-2}$ (Smith and Harlen 1991, Memmott *et al.* 1993, Hosking 1995, Paynter *et al.* in press). Soil seed banks below mature broom canopies in Australia vary from 190–2700 $m^{-2}$ in the Adelaide Hills (Steele 1993), 1100–12 300 $m^{-2}$ at Barrington Tops (Smith and Harlen 1991, Mihe 1992, J. Hosking unpublished data) and 4630–27 400 $m^{-2}$ around Braidwood (A. Sheppard and P. Hodge unpublished data). Less than 2% of seeds extracted from the soil were found to be non-viable. However in the absence of seed rain the seed bank declined by about 50% over one year (A. Sheppard and P. Hodge unpublished data).

### Hybrids

Many ornamental hybrids have been derived from crosses between *C. scoparius* and other *Cytisus* and *Genista* species. A number of these hybrids are sold in nurseries in Australia. Two red- and yellow-flowered hybrids, known as *C. scoparius* cultivar 'Andreanus' and *C. scoparius* cultivar 'Andreanus Aureus', have become naturalized in the Central and Southern Tablelands of New South Wales (Rowell 1991). Similar hybrids are also known to have become naturalized around Mount Hotham in Victoria and in Tasmania.

The taxonomy of ornamental broom cultivars is poorly defined in Australia. According to R. Rowell (personal communication) those in the Australian nursery trade now coin many names which may be descriptive and have nothing to do with original names.

### Population dynamics

Expansion of existing undisturbed broom stands appears to be slow, having been measured as 2–4 m over a seven year period in the Polblue area at Barrington Tops (Smith 1994a). Spread is more rapid in ungrazed open pasture, where it can reach 3–5 m a year (A. Sheppard and P. Hodge unpublished data). Long distance spread from broom stands occurs along streams and tracks following transport of seeds in the ways mentioned above.

Germination is highly seasonal. At two sites near Braidwood in New South Wales most germination took place in January–March (A. Sheppard and P. Hodge unpublished data). Over an 18 month period 0.6–4.0% of the viable seed bank germinated in autumn while only 0.007–0.2% germinated in spring. The number of seedlings appearing in each season is highly correlated with the size of the viable seed bank in disturbed plots ($R^2$ range 0.7–0.98 over three seasons at two sites). The number of seedlings was at least 10 times lower under mature broom or in undisturbed pasture compared with disturbed plots. One year after germination, seedlings were alive only in cultivated plots or in plots from which mature broom had been removed. However, all seedlings died in plots where other vegetation cover remained less than 20%. This mortality was due to dry conditions in summer and was not affected by the presence of grazing animals or insects. At the Braidwood sites, near the climatic limit of the weed in Australia, broom seedlings require grass species to help them establish. However, once established and above the grass layer (usually in their second year), the young saplings grow quickly and smother the associated vegetation as they mature. Approximately 6% of seedlings survive until flowering (Paynter *et al.* in press).

Plants live approximately 10–15 years in England (Waloff 1968) but can live longer than 23 years at Barrington Tops (Smith and Harlen 1991). Older broom plants collapse, resulting in less uniform shading of the ground and an increase in herbs (Smith 1994a). As stands age, the density of broom plants decreases and the size of surviving plants increases (Smith 1994a). However, there is little or no establishment of broom seedlings unless disturbance creates large gaps in the broom canopy (Smith 1994a), or until after death of most older broom plants in the absence of disturbance (J.M.B. Smith unpublished data). This is in sharp contrast to the native range where immediate regeneration of broom is largely prevented by the understorey vegetation (Memmott *et al.* 1993).

## Importance

*Detrimental*

Dense thickets of broom prevent re-establishment of native vegetation and impede access, particularly to watercourses. Thickets also harbour pest animals such as feral pigs (Parsons and Cuthbertson 1992) and other invasive animals such as blackbirds (Smith 1994b).

The impact of broom on native vegetation at Barrington Tops is documented in Smith (1994a) and Waterhouse (1988). In woodland at Barrington Tops, the often nearly continuous canopy of broom may largely eliminate herbs and tree seedlings from the understorey. Initially there is a decrease in the number and diversity of herb and shrub species due to shading by broom (Waterhouse 1988, Smith 1994a), although as broom stands age there is a partial recovery of the herb layer (Smith 1994a). However, without disturbance, the overstorey eucalypts largely fail to re-establish in broom infestations. Based on present trends, broom therefore appears likely to permanently change the structure, floristic composition and ecology of woodlands at Barrington Tops (Smith 1994a), such changes being of considerable conservation concern.

Increasing concern about the impact of broom on native vegetation has been expressed for other areas, such as the alpine area extending from northern Victoria through southern New South Wales and into the Australian Capital Territory (Fallavollita and Norris 1992).

Broom is also a problem in pasture grazed by cattle. In these areas broom stands increase in size and the pasture is smothered in and around the stands. Attempted broom control by various means (herbicides applied both aerially and from the ground, manipulation of grazing patterns) in pasture areas at the northern side of Barrington Tops and elsewhere have proved to be both expensive and largely ineffective.

Overseas, broom is a major problem of forestry in the USA (Clausen 1978, Isaacson *et al.* 1995), Canada (C. Dorworth personal communication) and New Zealand (Balneaves 1992), particularly in reafforestation after logging.

*Beneficial*

Broom and its hybrids are still widely sold as ornamentals in Australia. Broom has also been used as a substitute for hops, capers and coffee, for tanning, as a source of yellow dye and for medicinal purposes such as treatment of cardiac arrhythmia, as a diuretic, emetic and purgative, as a cure for dropsy and respiratory problems, and to induce abortions (Waterhouse 1988, Parsons and Cuthbertson 1992). Branches have been made into brooms and used for thatching and the bark has been stripped to make rope (Parsons and Cuthbertson 1992). The plant has also been used to stabilize sand dunes and to bind soil in road cuttings (Waterhouse 1988, Parsons and Cuthbertson 1992, Bossard and Rejmanek 1994). Although broom is considered to be a forestry pest in India it has also been used in that country as a nurse crop for commercial trees (Chinnamani *et al.* 1965).

### Legislation

Broom is declared noxious throughout South Australia and in parts of New South Wales, Victoria and Tasmania (Parsons and Cuthbertson 1992, E. Bruzzese personal communication).

## Weed management

*Herbicides*

The main chemicals used to control broom are picloram, triclopyr, glyphosate, fluroxypyr and metsulfuron-methyl (Parsons and Cuthbertson 1992). Before its withdrawal from use, 2,4,5-T or products containing 2,4,5-T, were widely used to control broom (Waterhouse 1988, Balneaves 1992). Research carried out in New Zealand has shown that the addition of some surfactants to glyphosate and metsulfuron-methyl increase the level of control achieved by these chemicals (Balneaves 1992).

The size and persistence of the soil seedbank leads to rapid and substantial regeneration by broom following attempts to control it chemically, mechanically or by fire. Moodie (1985) found at Barrington Tops that various herbicide treatments of broom, some in combination with burning, resulted in initial broom kill rates of 50–100%. Nevertheless, within a few years more broom plants were found in treated than control plots. Broom continues to regenerate from seed in treated areas such as Polblue Campsite (Barrington Tops) even after 19 years of sustained treatment.

*Other treatments*

**Human manipulations.** Conventional control measures presently carried out, mainly involving herbicides, manual pulling and local burning, have all proved to be ineffective. Removal of plants mechanically before they seed can be used to control isolated plants but is not practical over large areas (Parsons and Cuthbertson 1992). Small areas can be slashed and cultivated but this produces a seed bed ideal for broom seedling establishment (Parsons and Cuthbertson 1992). This must therefore be followed by repeated cultivations or grazing by sheep and goats.

Fire encourages germination of broom seeds (Bossard 1993). In areas of summer drought it has been suggested that prescribed burns of areas infested with broom could greatly decrease the number of seeds on and in the soil. These burns should be carried out under conditions that maximize soil heating so as to promote a flush of germination prior to summer drought (Bossard 1993). However, large soil seedbanks, the varied depths at which seeds are located in the soil (Mihe 1992, Steele 1993) and difficulties in safely burning areas of normally damp vegetation which only dries out at times of generally high fire danger, seem likely to make this an unworkable strategy in many infested areas of Australia.

**Grazing.** Sheep and goats are effective in controlling broom (Allan *et al.* 1993, C. Allan personal communication) but cannot be used in areas with high wild dog populations or in conservation areas where indiscriminate grazing is undesirable. At Barrington Tops, macropods and feral horses feed on isolated broom shrubs and keep them low and compact, but do not exercise any significant control. Similarly, in California browsing by deer, elk and jack rabbits may reduce broom biomass without exerting significant control (Bossard and Rejmanek 1994). Because cattle do not graze broom it is becoming an increasing problem where cattle are the only grazing animals.

*Natural enemies*

Much hope has been pinned on biological control of broom. Attempts have been made to control the plant biologically in the USA and New Zealand, without much success to date. Insects associated with broom were surveyed in central Europe, beginning in 1951, for the USA and this resulted in the release of two insects, a twig mining moth, *Leucoptera spartifoliella* Hübner (Lepidoptera: Lyonetiidae), and a seed feeding weevil, *Exapion fuscirostre* (Fabricius) (= *Apion fuscirostre* Fabricius) (Coleoptera: Apionidae) (Andres 1979). This biological control campaign ended with the last transfers of weevils from coastal areas of California to inland areas in 1968 (Clausen 1978). Further research was suspended, in part due to increasing concern over the value of woody legumes as ornamental or landscape plants (Andres 1979). Control by these agents has been ineffective (Bossard and Rejmanek 1994). However, preliminary surveys reported by Isaacson (1993) in Oregon indicate that *E. fuscirostre* reduces seed production by 75–90% after four years at a typical site. This insect is therefore having some impact on the rate of spread in Oregon by reducing the amount of seed available for dispersal. A mathematical model describing these conditions has predicted that for broom infestations in open pasture 99% seed predation is required to cause broom stands to become seed-limited, but concluded that lower levels of seed predation can limit spread and may cause population decline under a eucalypt canopy (Paynter *et al.* in press).

The New Zealand program began in 1981 with the importation of a chrysomelid, *Gonioctena olivacea* (Förster) for host specificity testing (Syrett 1989), but following preliminary host specificity tests, priority for further testing of this insect was lowered (P. Syrett personal communication). Two other insects have been released for control of broom in New Zealand in recent years, a seed feeding bruchid, *Bruchidius villosus* Fabricius (Coleoptera: Bruchidae) (Syrett 1993) and the broom psyllid, *Arytainilla spartiophila* Förster (Hemiptera: Psyllidae) (P. Syrett personal communication). A larger broom biological control program began in 1990 when Australia joined the New Zealand and International Institute of Biological Control program.

An excellent summary of information up until 1968 on insects which damage *C. scoparius* can be found in Waloff (1968). This summary deals with insects found on broom within the native European range, particularly in central southern United Kingdom. The impact of these insects was shown in an insect exclusion experiment conducted in this area (Waloff and Richards 1977). Although much of the fauna in this area is the same as in other locations in Europe, many further species are also found on broom in the latter areas (Hosking 1990, Mazay 1993). Insects have been found which feed inside seed pods, defoliate plants, feed on plant juices and mine stems. Other insects include mirid bugs which are both phytophagous and predacious (Waloff 1968). A number of mites, including *Aceria genistae* Nalepa (= *Eriophyes genistae* (Nalepa)) which produces galls (Boczek 1961, Castagnoli 1978, Manson 1989) and a number of diseases have been recorded on broom (Wilson and Henderson 1966, Sutton 1980, Sivanesan 1984). Many species of insects closely associated with broom have been transported around the world with the weed, either through transportation with ballast in ships or through the transport of live plants for horticulture (Waloff 1966). There are no records of such species in Australia, although the form of pea aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae) found on broom and the scale insect, *Parthenolecanium rufulum* (Cockerell) (Hemiptera: Coccidae) may have been introduced in this way.

The first biological control agent to be released in Australia was the broom twigminer, *Leucoptera spartifoliella*, which was released in New South Wales in February 1993 (Wapshere and Hosking 1993). This insect has established at Barrington Tops and near Braidwood, the sites of original releases. It is still too early to determine the level of damage likely to be caused by this moth in Australia. In New Zealand, where broom is also an introduced species, *L. spartifoliella* was unintentionally introduced before 1950; its populations and resulting damage are generally greater than in Europe (Syrett and Harman 1995) but to date the impact of this insect has not been quantified. The second agent, a broom psyllid, *Arytainilla spartiophila* was released in December 1994 and January 1995 at a number of sites in New South Wales. A third agent, a broom seed bruchid, *Bruchidius villosus* was released near Katoomba and near Braidwood at the end of 1995. It is too early to be sure that the psyllid and bruchid have established. It is planned to release further invertebrates as part of the ongoing program for biological control of broom in Australia.

Many insect species have been recorded on broom in its exotic range. In general these cause little damage, except for a few insects which are also associated with broom in its native range (Waloff 1966, Syrett 1993, Wapshere and Hosking 1993). Some native insects may cause local damage, such as occurs near Braidwood in southern New South Wales. In this area four cerambycids have been reared from girdled stems of broom. The larger *Uracanthus bivittata* Newman and *Strongylurus arduus* Elliott and McDonald are probably causing the girdling and the smaller *Pentacosmia scoparia* Newman and *Sybra acuta* Pascoe are probably secondary borers in the dead, girdled stems (Wapshere and Hosking 1993). Such attack may be associated with large stem girth and it may therefore appear more widespread once stands mature. A scale insect, *Parthenolecanium rufulum*, occurring at Barrington Tops and in southern New South Wales, causes death of sections of broom bushes and can reduce flowering and seed production. At Krawarree (near Braidwood) this insect was mostly responsible for a 33% reduction in seeds produced on control versus insecticide treated bushes in their first year of seed production. Damage caused by this insect appeared to have no effect on the number of seeds per pod (A. Sheppard and P. Hodge, unpublished data). This insect is of European origin where it is reported to have a wide host range (Singh 1967, Bürges and Gál 1981) and can be observed on broom, but in Australia it has been found only on broom. In southern New South Wales, broom seeds are also destroyed by *Etiella behrii* (Zeller) (Lepidoptera: Pyralidae) (Hosking 1995), an insect pest of a number of leguminous crops (Common 1990).

The aphid, *Acyrthosiphon pisum* is variable in abundance, causing extensive foliar-marking in some years. It also causes most insect-related damage to developing seedlings in Australia (A. Sheppard and P. Hodge unpublished data). This species may be the nominal subspecies that colonizes herbaceous legumes, or it may belong to the nominal subspecies *spartii* Koch, that colonizes woody Genistineae such as *Cytisus* and *Spartium*. Subspecies *spartii* has been recorded from Tasmania (M. Carver personal communication) and may have spread to the mainland.

Post-dispersal seed predation has been measured in an experiment repeated in four countries, including Australia. Such seed predation reached 80% per year in Australia but was higher in the native range and was considered to be largely caused by rodents (Paynter *et al.* in press). This clearly contributes to seed bank decline (see Population dynamics).

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