

The Biology of Australian Weeds.

30. *Vulpia bromoides* (L.) S.F. Gray) and *V. myuros* (L.) C.C. Gmelin)

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Name

Vulpia bromoides (L.) S.F. Gray, Nat. Arr. Brit. Pl. 2:124 (1821)

Vulpia myuros (L.) C.C. Gmelin, Fl. Bad. 1:8 (1805)

The common names are squirrel-tail and rat's-tail fescue respectively, but the two species are also known collectively as 'silvergrass', 'hairgrass' and 'silkygrass'. The genus *Vulpia* (named after the German chemist J.S. Vulpius) belongs to the tribe Festuceae of the family Poaceae.

Initially *V. bromoides* and *V. myuros* were included within the genus *Festuca*. However, as *Festuca* spp. are predominantly perennial and *Vulpia* spp. are almost entirely annual, they were an imperfect fit. *V. bromoides* and *V. myuros* are so closely allied that when both were described by Linnaeus, several botanists thought that he had described the same species twice. This confusion was probably intensified by the ability of both species to alter their growth form under adverse conditions (Henrard 1937).

The genus *Vulpia* contains approximately 20 species. For many years the genus was divided into five groups: *Vulpia*, *Loretia*, *Spirachne*, *Ctenopsis* and *Vulpiella*. In more recent times *Vulpiella*

and *Ctenopsis* have been considered to be genetically distinct (Cotton and Stace 1977, Bulinska-Radomska and Lester 1986). The genus is now recognised as having four sections: *Vulpia*, *Spirachne*, *Monachne* and *Loretia* (Cotton and Stace 1977). *Monachne* was reinstated by Cotton and Stace (1977) and follows an earlier grouping of the genus by Dumortier (1824). *V. bromoides* and *V. myuros* are members of section *Vulpia* which is thought to be of more recent origin compared to the other sections, having advanced floral features, an annual habit, and a tendency to autogamy and polyploidy (Bulinska-Radomska and Lester 1988).

A total of five species of *Vulpia* have been recorded in Australia (Hnatiuk 1990). *V. bromoides* and *V. myuros* will be dealt with in detail in this paper. A distinct form of *V. myuros*, sometimes referred to as *V. megalura* (Nutt) Rydb., has lemmas that are ciliate towards the apex, and occurs throughout the range of *V. myuros* (Jacobs and McClay 1993).

Description

Both of the species described below are annuals. The following taxonomic description is taken largely from Lamp *et al.* (1990), Wheeler *et al.* (1982) and Stace (1980).

Slender, erect, tufted annuals from 5–60 cm high (Figure 1a). Culms erect, slender,

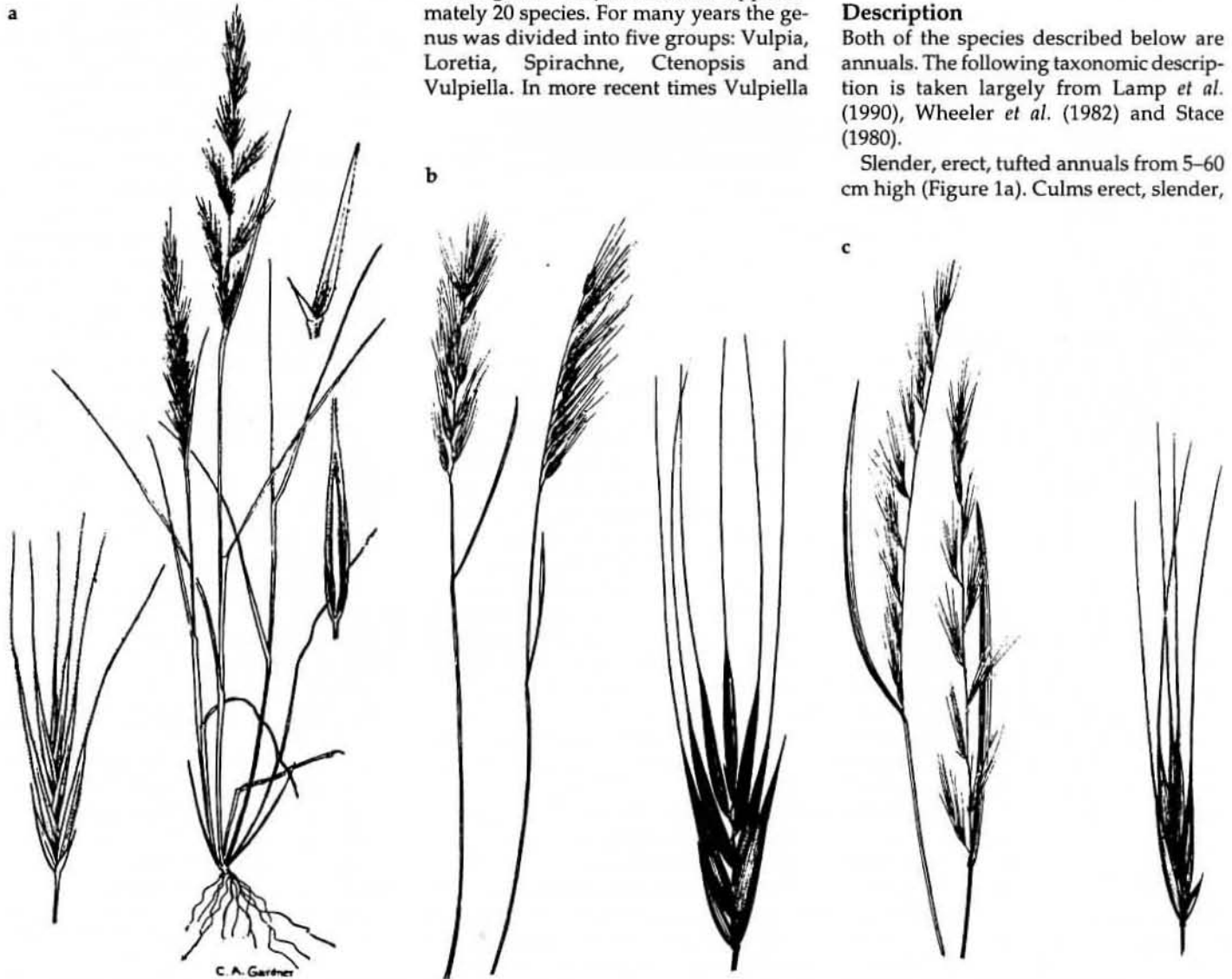


Figure 1. (a) *Vulpia myuros*, typical growth habit (from an original by C.A. Gardner, reproduced with the permission of the WA Herbarium). Enlarged views of panicle and spikelet (b) *V. bromoides*, (c) *V. myuros* (originally published in Haflinger and Scholz (1981), reproduced here with the permission of Ciba Australia).

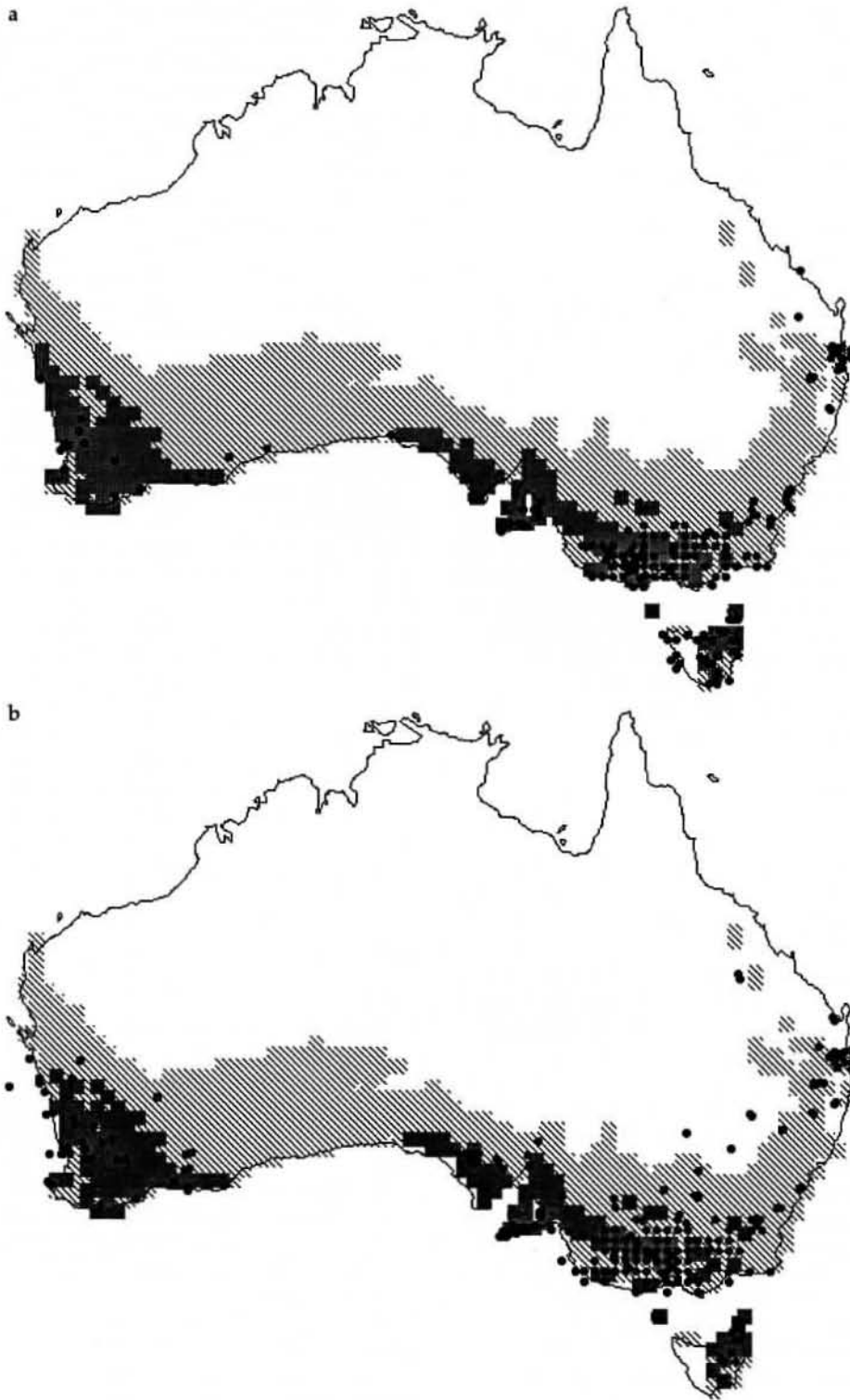


Figure 2. The predicted distribution with locations that match the ideal climate by 80% or greater (grey) and locations that match the ideal climate by 50–79% (diagonal line), plus the locations of existing herbarium records (solid circles) for (a) *V. bromoides* and (b) *V. myuros*. The mapped prediction is based on a $1 \times 1^\circ$ grid.

tufted or solitary, often branched (*V. bromoides*). Leaf blades rolled in the bud, green and finely pointed, 1–14 cm long, 0.5–3 mm wide, upper surface with five to seven pubescent veins, rough near the tip and on margins, lower surface slightly glossy, glabrous or with a few hairs, indistinct mid-veins. Ligule membranous to 1 mm long, white. Auricles absent. Leaf sheath split, glabrous or with scattered

hairs, usually rounded, sometimes compressed or slightly keeled, sometimes purple tinged near base. Inflorescence a narrow one-sided panicle carried well clear of the flag leaf (*V. bromoides*) or partly included in upper-most leaf-sheath (*V. myuros*), erect or slightly nodding, lanceolate, rather loose to compacted, 1–10 cm (*V. bromoides*) or 5–35 cm (*V. myuros*) long. Inflorescence is green-purple in colour,

pedicels 1–4 mm long and thickened. Inflorescence length may be reduced to a spike or a single spikelet under adverse conditions (Cunningham *et al.* 1992). Spikelets are awnless, 7–16 mm long, oblong to wedge shaped, disarticulating above the glumes and between the lemmas, 5–10 florets. The glumes are unequal and finely pointed and are the main determinant between the two species.

Vulpia bromoides. The lower glume is 2.5–5 mm long, one half to three quarters the length of the upper (Figure 1b); upper glume 4.5–9 mm. Lemma 4.5–7 mm long, rounded at the back, five-nerved, florets partially overlapping each other. Awn terminal, slender and roughened, up to 13 mm long. Paleas sub-equal to lemmas, two roughened keels. Anthers one (to three), 0.3–0.6 mm long and included at anthesis. Ovary glabrous.

Vulpia myuros. The lower glume 0.4–2.5 mm long, one tenth to two fifths as long as the upper (Figure 1c); upper glume 2.5–6.5 mm (including awn of up to 1 mm). Lemma 4.5–7.5 mm with an awn usually one to two times as long, 0.8–1.3 mm wide, finely five-veined. Paleas sub-equal to lemmas, two roughened keels. Anthers 1 (to three), 0.4–0.8 mm and included at anthesis. Ovary glabrous.

The basic chromosome number of the genus *Vulpia* is seven. *V. bromoides* is diploid ($2n=14$) and *V. myuros* is hexaploid ($2n=42$) (Cotton and Stace 1977).

History

Vulpia bromoides and *V. myuros* were introduced to Australia soon after settlement. The exact method of entry is unknown but it is likely that introduction occurred via ships' ballast and in contaminated forage, wool or attached to livestock (Kloot 1986). Seeds of *V. myuros* were found in imported grass seed (particularly perennial ryegrasses) as late as 1952 (Broad 1952). *V. bromoides* was listed as an ornamental grass in a seed catalogue published in 1886, so it is possible that it was introduced in this way to some areas and is in fact a garden escape! (Pascoe 1886).

Vulpia bromoides and *V. myuros* were first recorded in Australia soon after settlement and usually in areas of initial settlement; Tasmania 1837, Victoria (Yarra) 1852 and South Australia (Hahndorf) 1848. Later collections were well inland of the original settlements; Western Australia (Kellerberrin) 1891, Victoria (Swan Hill) 1889, interior of New South Wales 1880. This indicates that they entered Australia in the early years of European settlement and spread quickly to suitable environments, probably with stock and human movements as agricultural expansion took place.

Vulpia bromoides and *V. myuros* are now widely distributed (Gardner 1952,

Lazarides 1981, Lamp *et al.* 1990). Their long presence in Australia coupled with their wide range through the southern half of the continent suggest that they have reached the limits of their distribution.

Distribution

Both *V. bromoides* and *V. myuros* are natives of the western Mediterranean, south-western and central Europe (Cotton and Stace 1976, Stace 1980). In the northern hemisphere, *V. bromoides* is distributed further north than *V. myuros*, occurring as far north as Scotland and Sweden. In north-western Europe *V. bromoides* is the more common of the two species, except where *V. myuros* has spread along railway lines (Cotton and Stace 1976). *V. bromoides* is occasionally found in Russia and Western Asia, and is naturalized in North and South America and Australasia.

Vulpia myuros is widespread throughout southern and central Europe, reaching as far to the north-east as Poland and Russia and to the British Isles in the north-west (Stace 1980). In most parts of Europe *V. myuros* is the most common species and its range extends east to north-western India (Cotton and Stace 1976). *V. myuros* is naturalized in North and South America, East Asia (Japan), South Africa and Australasia (Cotton and Stace 1976).

The potential distributions of *V. bromoides* and *V. myuros* in Australia have been estimated using a bio-climatic computer model (Nix 1986). The selectivity of the program was increased by including data on the distribution of the two species in their countries of origin and data on germination and other life cycle requirements. Herbarium records were accessed from the Environment Research Information Network (ERIN, Anon. 1995) via the Internet and combined with the predicted distribution (Figure 2).

Vulpia bromoides and *V. myuros* are widely distributed throughout Australia, occurring between latitudes 25 to 44°S, but occurring most commonly in southern Australia (Hnatiuk 1990). *V. myuros* is found as far north as the Darling Downs in Queensland (Hnatiuk 1990).

Habitat

Climatic requirements

Vulpia bromoides and *V. myuros* occur over a wide range of climatic conditions in Australia, although Mediterranean-type climates appear to provide the optimum conditions of cool winters and warm summers, with the absence of severe drought, and a predominance of winter/spring rainfall. Both species have been collected from coastal to inland regions (1200 to 200 mm annual rainfall), although most of their range is in areas of greater than or equal to 300 mm annual rainfall. Plants are

sensitive to drought (Rossiter 1966) as they are shallow rooted (Ozanne and Asher 1965). In consequence of this they are mostly found in the higher rainfall areas of southern Australia (Velthuis and Amor 1983). Their range encompasses the major cereal and livestock regions of southern Australia.

Vulpia bromoides and *V. myuros* have been found from sea level up to 610 m in the British Isles (Hubbard 1968) and at greater than 1000 m elevation on the northern tablelands of New South Wales (McIntyre and Whalley 1990)

Substratum

In Western Australia, *V. myuros* is found mainly on light to medium textured soils which tend towards acidity (Rossiter 1966). A survey of the pastures of south-eastern South Australia found that soils characterized by low to moderate potassium and phosphate status had the highest incidence of *V. myuros*. However, *V. myuros* was present on nearly all of the eight soils surveyed, which had a pH range of 4.5–9 and varied in texture from sands to clay soils (Tiver and Crocker 1951).

More recently in New South Wales, McIntyre and Whalley (1990) observed that *V. myuros* was common over a range of parent material and that plant frequency was associated with increasing soil fertility (granitic < sedimentary < basaltic), but could not confirm this statistically.

The potassium status of the soil surface is very important for the growth of *Vulpia* spp. *Vulpia* spp. have a low requirement for potassium to reach 50% maximum growth (Rossiter 1966). Ozanne and Asher (1965) determined that *V. myuros* had a low concentration of potassium in its seed (total seed potassium is closely related to seed weight and *V. myuros* has a very small seed, approximately 0.5 mg). When grown in potassium deficient medium, the rooting depth of *V. myuros* was only 3 cm, but, after the addition of potassium, rooting depth increased to 18 cm (Ozanne and Asher 1965). Seeds germinated at extremely low potassium levels, but very few seedlings emerged successfully (Ozanne and Asher 1965). Mean effective rooting depth (90% of roots to specific depth) of *V. myuros* was 23 cm after 126 days growing in a sandy soil with unlimited nutrients (Ozanne *et al.* 1965).

Vulpia myuros grows well on soils of low to intermediate phosphorus status and exhibits a limited response to applied phosphorus (Rossiter 1964). The proportion of *V. myuros* present in the pasture declined at higher rates of applied phosphorus (>125 kg ha⁻¹ of superphosphate, approximately 9% phosphorus). Of a range of annual species tested, *V. myuros* had the highest rate of phosphate absorption at low phosphate concentrations, and was

able to achieve maximum yields at solution concentrations as low as 1 µM (Asher and Loneragan 1967). At high phosphate concentrations *V. myuros* was unable to absorb phosphate at increasing rates (Loneragan and Asher 1967).

Response of *V. myuros* to nitrogen application appears to depend on plant density. Cocks (1974) determined that, at low densities, both *Lolium rigidum* Gaudin and *Hordeum leporinum* Link had a greater dry weight increase than *V. myuros* following nitrogen applications. At a higher plant density, *V. myuros* responded as well as *L. rigidum* and better than *H. leporinum*. *L. rigidum* and *V. myuros* both had greater absolute response than *H. leporinum* when response to nitrogen was compared at similar amounts of available herbage (Cocks 1974).

From the studies described above it becomes clear that *V. myuros* (and in all probability *V. bromoides*) tolerates soils with low potassium, phosphorus and nitrogen status. This may explain why *Vulpia* spp. are often found to dominate pastures where soil fertility has been allowed to decline. On soils of higher fertility *V. bromoides* and *V. myuros* are likely to suffer the effects of competition from other grass species such as *L. rigidum*. A related species, *V. membranacea* (L.) Dumort., (*V. fasciculata* (Forssk.) Samp.) has shown optimum performance (in terms of shoot dry matter yield) at low nutrient concentrations (Austin and Austin 1980).

Plant associations

In Europe *V. bromoides* and *V. myuros* are essentially members of heaths, hill grassland and roadside communities and are often very common on roadsides (Hubbard 1968), waste and cultivated land.

Australian communities include waste places, native and sown pastures and sheep camps (Forcella 1984, McIntyre and Whalley 1990). Although not originally noted as crop weeds, *V. bromoides* and *V. myuros* are becoming more common in direct drilled crops. Tiver and Crocker (1951) reported *V. myuros* as being one of the first of the annual grasses to invade partially improved (superphosphate applied and *Trifolium subterraneum* L. seeded) native pastures.

The plants most frequently associated with *V. bromoides* and *V. myuros* are other annual grasses (*L. rigidum*, *Hordeum* spp., *Bromus* spp.) and introduced, naturalized, broadleaved annual plants including subterranean clover (*T. subterraneum*), cape-weed (*Arctotheca calendula* (L.) M. Levyns) and geranium (*Erodium* spp.). These species are the basic components of pastures in the cereal and grazing areas of southern Australia. *Vulpia* spp. are usually subdominant in the sward, but may become dominant following the removal of the

dominant species. This has been observed when paddocks formerly dominated by annual ryegrass (*L. rigidum*) have been taken over by *V. bromoides* and *V. myuros* following the removal of the annual ryegrass with herbicides (A. Wallace unpublished data).

Growth and development

Morphology

Vulpia spp. are slender, erect, tufted grasses usually growing to a height of 20 cm.

Vulpia myuros assumes a prostrate form under continuous grazing (Smith *et al.* 1972). It has been observed that *V. bromoides* growing on sheep camps is more prostrate than when found growing away from these areas (Yeoman 1980). This may be a mechanism to prevent excessive grazing, by reducing accessibility.

Perennation

Vulpia bromoides and *V. myuros* are annuals and survive adverse conditions (high

summer temperatures and dry periods) as seed. *V. bromoides* and *V. myuros* seed prolifically in spring (Scott 1990) and most seeds become lodged at the soil surface.

Physiology

The growth rate of *V. myuros* was not different to that of annual ryegrass (*L. rigidum*) between May and June (8 compared with 10 kg DM ha⁻¹ d⁻¹), but was significantly less after late June. *V. myuros* increased to an August maximum of 22 kg DM ha⁻¹ d⁻¹, about half that of *L. rigidum* (Smith *et al.* 1972). *V. myuros* plants were small but grew at the same rate as *L. rigidum* under grazed conditions (Broom and Arnold 1986).

Dillon and Forcella (1984) studied the growth of both *V. bromoides* and *V. myuros* over a range of photoperiods and temperatures. Generally the vegetative growth of both species increased approximately linearly and/or asymptotically over a four month period at high temperatures (28°/20°C) (Figure 3). Exponential growth occurred initially at intermediate

temperatures (23°/15°C) but this rate slowed after around 10 weeks. However, at low temperatures (18°/10°C) exponential growth occurred up until the end of the experiment at 16 weeks for both species. For the initial growth period (first 7–10 weeks after sowing), high temperatures and long photoperiods led to the greatest growth rates for both species with the growth rate of *V. myuros* usually greater than that of *V. bromoides*. For the final period of growth, rates remained constant or declined at high to intermediate temperatures, although at the lowest temperature dry matter production continued to increase exponentially for both species. By the end of the experiment (16 weeks), plants grown under 18°/10°C were 50–100% larger (dry weight per plant) than those grown under the other two temperature regimes. In addition, at low temperatures an eight hour photoperiod was the most favourable for maximum vegetative growth for both *V. bromoides* and *V. myuros* (Dillon and Forcella 1984).

Phenology

Seeds of *V. bromoides* and *V. myuros* have an after-ripening requirement of 2–3 months in the field; this increases to 4–5 months under glasshouse conditions (Chancellor 1984, Dillon and Forcella 1984).

The annual growth cycle of *V. bromoides* and *V. myuros* begins with germination following substantial rainfall, which is usually when precipitation exceeds monthly pan evaporation (March–May) (McGowan 1970, Dillon and Forcella 1984, Amor 1985, Scott and Blair 1987). McGowan (1970) observed autumn dormancy in *V. bromoides* over two seasons, 1967 and 1968. During the 1967 season, February rainfall totalled 42 mm and no germinations were recorded. The lack of germination following this quantity of rainfall may be explained by the warm conditions that coincided with the rainfall. McGowan (1970) provides a ratio of precipitation/evaporation (P/E) of 0.23 for February 1967. Rainfall was considered to be effective if the P/E ≥ 0.3.

Dillon and Forcella (1984) did not record germination of *V. bromoides* and *V. myuros* in the field until after at least 50 mm of monthly rainfall. The total amount of rainfall required would probably decline as the temperature drops and considerably less rainfall may result in significant germination towards the end of autumn.

Most germinations would be expected between March and early June. The soil-seed bank is generally short lived and given appropriate moisture conditions, most seed germinates readily and uniformly (Dillon and Forcella 1984).

Reproduction

Floral biology

Fertile florets of *V. bromoides* and *V. myuros* are cleistogamous, have usually only one or two stamens and are fully self-fertile (Cotton and Stace 1977, Stace 1980, Ainscough *et al.* 1986). In the majority of *Vulpia* species the one to two (sometimes three) most apical florets in each spikelet are reduced in size and are either male or sterile (Cotton and Stace 1977).

For both species, the number of flowering culms produced was greatest at lower temperatures (18°/10°C). Length of photoperiod influenced the species differently, *V. bromoides* being essentially insensitive to photoperiod (Flood and Halloran 1982, Dillon and Forcella 1984) and *V. myuros* producing significant numbers of flowering culms only during an eight hour photoperiod. *V. bromoides* produced more culms under intermediate temperatures (23°/15°C). High temperatures (28°/20°C) prevented flowering for both species (Dillon and Forcella 1984).

Flowering occurs during spring, with *V. bromoides* and *V. myuros* having similar flowering times in the field (Jones 1992). It takes approximately 18 days from flowering to seed maturity (P. Stewart unpublished data). This period varies from 7 to 30 days depending on growing conditions. Sites with shorter growing seasons or where late spring rains do not fall have the

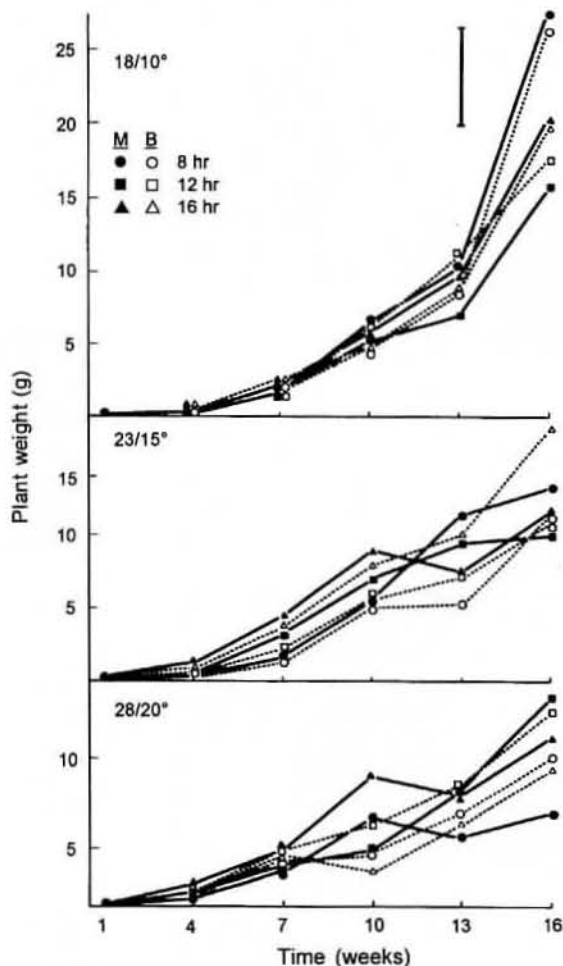


Figure 3. Total plant dry matter accumulation of *V. bromoides* (B) and *V. myuros* (M) at three temperatures, three photoperiods and six harvest dates. Each value is an average of four pots each containing two plants. Bar represents LSD (P=0.05) among mean values at the last harvest (from Dillon and Forcella 1984).

shortest period between flowering and seed maturity.

Seeds are released shortly after maturity and are dislodged from the parent plant by wind or animal disturbance. Seeds are typically shed in October–November (Scott 1990).

Seed production and dispersal

The unit of dispersal is a single floret with the next highest rachilla segment. The spikelet disarticulates at the base of each floret and leaves the pedicel and two glumes on the parent plant (Cotton and Stace 1977). Seeds are small and attach easily to animals and clothing. *Vulpia* spp. are a major cause of vegetable fault in wool and they may also work into the skin of livestock, causing hide damage (Whittet 1969).

Seed production per plant varies from year to year in response to plant density, climatic and edaphic factors. Seed weight has been recorded as 0.59 mg (*V. bromoides*) and 0.49 mg (*V. myuros*) (Dillon and Forcella 1984) although Ozanne and Asher (1965) recorded seed of *V. myuros* to weigh 0.63 mg. *V. fasciculata* (not widespread in Australia) has been recorded as having very variable seed production characteristics in the United Kingdom; for example, 1–3.3 inflorescences per plant, 2.9–63.7 spikelets per inflorescence and 0.77–4.37 caryopses per spikelet depending on site and soil type (Watkinson 1978).

Physiology of seeds and germination

Provided after-ripening has occurred, fresh seed of *V. bromoides* and *V. myuros* can germinate and emerge in the field at any time (Dillon and Forcella 1984).

Seeds are intolerant of burial and generally germinate from the surface or immediately below the surface to approximately 10 mm depth. The greatest proportion of *V. bromoides* seeds are found in the top 5 mm of soil (Yeoman 1980). Placing seeds at depths of 50 mm (Dillon and Forcella 1984) and 76 mm (McGowan 1970) reduces emergence considerably.

The percentage of *V. myuros* seed that was found emerging at depth (to 50 mm) was greater than that of *V. bromoides* (Dillon and Forcella 1984). This is unusual as the seed of *V. myuros* was significantly smaller than that of *V. bromoides* in this experiment, and the larger seeded species would have been expected to be less inhibited by planting depth.

Seedling weights were found to be greater when seeds were planted at shallower depths, with *V. myuros* seedlings being consistently heavier than *V. bromoides* seedlings planted at the same depth (Dillon and Forcella 1984).

Vulpia bromoides and *V. myuros* are both able to germinate under light and dark conditions over a range of temperatures. Germination (up to 10%) commenced

within two days in darkness at temperatures between 20–28°C for both species. Exposure to light increased the range of temperatures stimulating germination to 17–31°C and proportion of seeds germinating to approximately 70% in the same time period (Dillon and Forcella 1984). After seven days the range of temperatures where germination occurred had increased to 6–28°C dark versus 2–31°C light (Dillon and Forcella 1984). Optimum temperatures for germination were 12–23°C (both species) in darkness and 9–28°C (*V. bromoides*) and 12–31°C (*V. myuros*) in light. Under both light and dark regimes *V. myuros* had a greater proportion of seeds germinating at higher temperatures than did *V. bromoides* (Dillon and Forcella 1984). *V. myuros* germinated somewhat faster than *V. bromoides* in darkness. Rate of germination for both species was greater in light, with half maximum germination being reached in 1.5 days light compared with three days darkness (Dillon and Forcella 1984).

While germination is governed more by the abundance of soil moisture, patterns of vegetative growth and floral development for both species generally parallel the climatic conditions experienced during the growing season. Plants which may germinate 'out of season' would be likely to progress quickly through the life-cycle, probably with minimal emphasis on vegetative growth. These plants, while not contributing greatly to the seed bank, may act as sources of seed to enable the population to survive the effects of control strategies, as they would avoid applied controls as seed.

Hybrids

Hybrids are rare although some crosses between *V. bromoides* or *V. myuros* with *Festuca rubra* L., *F. junicifolia* St-Amans (Hubbard 1968, Stace 1980, Ainscough *et al.* 1986, Bulinska-Radomska and Lester 1988) and *F. nigrescens* Lam. (Ainscough *et al.* 1986) have been recorded in the British Isles. It is thought that due to the cleistogamous nature of *V. bromoides* and *V. myuros*, any cross breeding is the result of a female *Vulpia* crossing with a male *Festuca* (Ainscough *et al.* 1986). This character also leads to the relative rarity of hybrids in the wild. Hybrid populations persist only a few years and exhibit a high degree of sterility (Ainscough *et al.* 1986).

Population dynamics

Vulpia bromoides and *V. myuros* emerge rapidly in glasshouse trials and from cultivated soil (Jones 1994). Populations of *Vulpia* spp. may have been considered transient in the past because of this. When emergence was studied in the field, only 21% of the *V. myuros* and 46% of the *V. bromoides* seed bank emerged in the first seven months. Total emergence was found

to be staggered over a 16 month period (Jones 1994). When samples from the same seed lot were studied in a glasshouse environment greater than 95% of seeds from both species emerged within 14 days.

Vulpia bromoides and *V. myuros* produce extremely large soil seed banks (Jones and Whalley 1993), a proportion of which can persist for at least 3 years (Jones *et al.* 1992). The proportion of residual seed varied from 1% in a closely grazed pasture to approximately 7% in less frequently grazed pasture (Jones 1992).

In a Californian study where seed rain was excluded for one season, recruitment of *V. bromoides* was found to be much less in the exclosures (28 plants m⁻²) than in areas where seed rain had not been excluded (904 plants m⁻²) (Peart 1989a). This indicates that very few recruits come from the soil seed bank, approximately 3%. *V. bromoides* recruitment was highest in patches with the highest biomass of *V. bromoides*, which coincided with where the highest seed rain density occurred (Peart 1989a).

When *V. bromoides* was introduced into gaps in existing perennial grass vegetation, seed set was well below that found in patches of dense *V. bromoides* (Peart 1989b). Seeds were produced equivalent to 0.018 seeds per seed introduced. In the second year after introduction no *V. bromoides* seedlings were detected (Peart 1989b). Peart (1989b) concluded that a continual dense seed rain from a nearby source is required to maintain a population of *V. bromoides* in a perennial dominated patch.

The production of dormant seeds, despite the small proportion produced, greatly increases the likelihood that *Vulpia* spp. will maintain a low-level population at sites favourable for growth. Provided that the conditions limiting survival of *Vulpia* spp. do not continue for longer than the seed dormancy, *Vulpia* spp. will be able to re-establish a population when conditions again become favourable.

In the northern tablelands of New South Wales the composition of the naturalized *Vulpia* spp. populations was found to be 38% *V. myuros* and 61% *V. bromoides* (McIntyre and Whalley 1990). Of the 100 sites surveyed *V. bromoides* and *V. myuros* were found in a mixed population in 89 cases (McIntyre and Whalley 1990). *V. bromoides* was more prevalent in southern and central New South Wales than *V. myuros*, 73 versus 26% in the cropping zone and 76 versus 24% in the pastoral zone (Dowling *et al.* 1993). The species composition ratio of approximately 30:70% (*V. myuros*:*V. bromoides*) occurred in both studies. However, as both surveys were conducted in the same year, 1989, this may account for the similarity in results.

Throughout Australia there are more herbarium records of *V. myuros* than

V. bromoides. It may be inferred from this that *V. myuros* is the more widespread of the two species in Australia although not necessarily the most common.

Habitat may alter frequency of each species in a population. *V. myuros* was more abundant on sheep camps than *V. bromoides* (McIntyre and Whalley 1990) although the frequencies of occurrence of both species were higher off sheep camps (McIntyre and Whalley 1990).

McIntyre and Whalley (1990) theorized that *V. myuros* may exist in ecotypes tolerant to disturbance and/or on soils of higher nutritive value (see earlier), than *V. bromoides*. That *V. bromoides* may lack tolerance of these habitats may also be true. However, *V. myuros* would experience increasing competition from other species when growing in soils with higher nutritive value, so the real advantages of increased tolerance may be very slight.

Small differences in germination, growth, and flowering behaviour may result in asynchronous, fluctuating populations of the two *Vulpia* spp. at a single location (McIntyre and Whalley 1990). *V. myuros* germinates faster and over a wider range of conditions than *V. bromoides*. *V. myuros* seedlings can emerge from greater depths and with higher seedling weights than *V. bromoides*. However, *V. bromoides* is able to flower over a wider range of temperature/photoperiod combinations than *V. myuros*. The superior reproductive ability of *V. bromoides* may be the factor that enables it to coexist with, and often dominate, *V. myuros* in mixed populations (Dillon and Forcella 1984).

Importance

Detrimental

Vulpia bromoides and *V. myuros* are becoming more prevalent in both pastures and crops and have been identified as a

major problem in these situations (Reeves 1987).

In crop situations, *V. bromoides* and *V. myuros* are less competitive (Poole *et al.* 1986, Poole and Gill 1986, Poole and Gill 1987) than weeds such as *L. rigidum* and *Avena fatua* L. (Poole and Gill 1986). This could be due to the relative time of germination of the weed and the crop. *V. bromoides* and *V. myuros* are not tolerant of cultivation and are more likely to occur in direct drilled crops. Forcella (1984) found significant reductions in wheat grain yield when *Vulpia* spp. were present (Table 1), though this reduction may have been due to the other species present.

Field populations of 43 000 seedlings per square metre of *V. myuros* have been observed in pastures (Scott and Blair 1987). *V. bromoides* and *V. myuros* may contribute to competition in pastures, particularly during establishment. In a study of competition, lucerne (*Medicago sativa* L.) seedlings were less affected at emergence by increasing densities of *V. myuros* than were phalaris (*Phalaris aquatica* L.) seedlings (Scott and Blair 1987). The growth of both pasture species was considerably reduced by the presence of 4000 plants per square metre of *V. myuros*. Further increases in the density of *V. myuros* did not lead to continued reductions in the growth of lucerne and phalaris, as intraspecific competition is thought to have commenced in the *V. myuros* population.

Vulpia spp. are able to harbour the organism that causes take-all (MacNish and Nicholas 1987) and may be more effective as a carrier of this disease than other annual grass species, although results varied considerably between the sites studied (Rovira *et al.* 1990). *V. myuros* has also been found to act as a host for the nematode that causes annual ryegrass toxicity (Riley and McKay 1991), and more work on the causal bacteria in the association is being carried out.

In common with other annual grass species, *V. bromoides* and *V. myuros* are amongst the principal hosts of the crop pest webworm (*Hednota* spp.) (Button 1963).

Vulpia bromoides and *V. myuros* have small sharp seeds that easily attach to the wool of passing sheep (Whittet 1969). Hay infested with *V. bromoides* and *V. myuros* can cause injury to livestock. In an animal feeding experiment conducted at Wagga Wagga, 11 of the 12 animals fed infested hay developed severe mouth ulceration (Leys and Dowling 1992).

While not as apparent a contaminant as barley grass (*H. leporinum*), *V. bromoides* and *V. myuros* may sometimes cause

the same amount of damage due to an abundance of small seeds. The value of annual losses in potential output to the Australian wool industry was estimated in 1988 to be \$A152 million for *Hordeum* spp., *Bromus* spp. and *Vulpia* spp. collectively (Hamilton 1990) and, more recently, estimates for *V. bromoides* and *V. myuros* alone are set at \$A50 million per annum (Leys and Dowling 1992).

Residues of *Vulpia* spp. have been found to have an adverse effect on the biomass production of wheat plants (Pratley 1989). Dry matter yield was reduced by as much as 66% following application of degraded residue at rates of less than 1 t ha⁻¹ (Pratley 1989).

The phytotoxicity of *V. myuros* residue was determined by incorporating it into soil prior to aqueous extraction (An *et al.* 1993). Residue alone reduced wheat germination by 75% while a mix of 1:10 (w/w) residue to soil did not alter per cent germination. Mixes in the ratio of 1:1 and 1:5 had greater phytotoxicity than 1:10, but not as great as residue alone.

The allelopathic effect of *V. bromoides* and *V. myuros* appears to be greater when residues have been degraded in some way, either naturally *in situ* from exposure to seasonal conditions on the soil surface, or artificially following treatment with ultra violet light (Pratley 1989, Pratley and Ingrey 1990). Treatment of residue (equivalent to 2 t ha⁻¹) with ultra violet light ± moisture accentuated the effect of the residue on the germination of a range of plant species. A reduction of up to 38% in lucerne (*M. sativa* cv. Aurora), 33% in wheat (*Triticum aestivum* L. cv. Vulcan) and 49% in phalaris (*P. aquatica* cv. Sirolan) was recorded relative to control treatments, although germination of canola (*Brassica campestris* L. cv. Jumbuck) was unaffected (Pratley and Ingrey 1990).

The greatest effect of allelochemicals is likely to follow a dry summer/autumn period with no rain to leach toxins, and in farming systems where there is minimal soil disturbance and residues remain on the soil surface (An *et al.* 1993). Heavy *V. bromoides* and *V. myuros* residues can be managed by strategic use of autumn burning (Pratley and Ingrey 1990).

Vulpia myuros forma *megalura* has been found to release allelochemicals (Scott 1975). In a study on the effect of shoot material on the germination of a number of perennial legumes and grasses, Scott (1975) found that all species with the exception of *Trifolium repens* L. were adversely affected when compared to the control. Generally, germination of grass species was more strongly suppressed than that of legume species.

Beneficial

Vulpia myuros has been used in California as an erosion control agent. Under the

Table 1. Average final harvest weights of *Vulpia* spp. and wheat grain according to the date when total weed control stopped. *Vulpia* spp. were allowed to establish at will after these dates. (Modified from Forcella 1984).

Date weed control stopped (1981)	Wheat grain yield (t ha ⁻¹)	<i>Vulpia</i> spp. tops yield (g m ⁻²)
July 15	0.7	122
July 31	0.65	27
August 5	0.85	51
August 10	1.0	21
August 20	1.5	17
August 30	1.6	12
September 9	1.9	13
September 19	1.5	5
September 29	1.35	3
October 9	1.6	1
October 29	1.8	1
November 18	1.65	1

Table 2. Rate of simazine and paraquat (kg a.i. ha⁻¹) applied as a mixture and level of control of *Vulpia* spp. in three studies.

Study	Simazine	Paraquat	Reduction in density of <i>Vulpia</i> spp. (%)
Leys and Plater (1993) (Data from site 5 is presented)	0.5	0.02	75
	0.5	0.04	95
	0.5	0.06	99
	0.625	0.02	99
	0.625	0.04	99
	0.625	0.06	99
	0.75	0.02	97
	0.75	0.04	99
	0.75	0.06	99
Gameau and Dickinson (1994)	0.25	0.03	82
	0.375	0.03	90
Wallace (1993)	0.25	0.1	98
	0.375	0.1	99

cultivar name of Zorro, *V. myuros* has been seeded to stabilize roadbanks, construction sites, mine spoils and hillside vineyards and orchards. Zorro has shown superior performance on infertile, shallow and droughty soils (Slayback 1985). Zorro has been found to perform better than *Lolium multiflorum* Lam. and *Bromus mollis* L. on dry and acid sites. When seeded in mixtures with perennials and shrubs it gives initial erosion control and permits the establishment of longer lived plants (Slayback 1985).

Vulpia bromoides and *V. myuros* have limited forage value. While they are eaten by livestock, if other pasture species are available they will be given preference over *Vulpia* spp.

Weed management

Herbicides

Pasture manipulation. The six currently available herbicides registered for use in Australian pastures for the selective control of grass weeds belong to two chemical groups, the aryloxyphenoxypropionates ('fops') and cyclohexanediones ('dims'). *V. bromoides* and *V. myuros* are tolerant to chemicals of both groups (Dillon and Forcella 1984, Code 1986, Scott and Blair 1987, Brewster and Spinney 1989), with the possible exception of the 'dim' clethodim (Leys *et al.* 1988, Stephenson *et al.* 1993). Clethodim reduced *V. myuros* dry weight by up to 80% when rates of greater than 0.1 kg a.i. ha⁻¹ were applied (Leys *et al.* 1988). A rate of 0.1 kg a.i. ha⁻¹ (costing \$A36.60 per hectare) is well beyond the 0.06–0.09 kg a.i. ha⁻¹ rate required to control annual ryegrass and would clearly not be economical to apply for control of *V. bromoides* and *V. myuros*.

Vulpia bromoides and *V. myuros* are susceptible to simazine applied in autumn. Rates as low as 0.25 kg a.i. ha⁻¹ will reduce *V. bromoides* and *V. myuros* populations considerably (Leys, Plater and Lill 1991), although increasing the rate to 0.5 kg a.i.

ha⁻¹ reduced the variability of the control. Time of application will alter the effectiveness of simazine. Applications of simazine in April and July were found to be less effective than applications in May (Leys, Plater and Lill 1991). The differences in efficacy were thought to be due to a combination of germination pattern and soil moisture. In this study (Leys, Plater and Lill 1991) most of the *V. bromoides* and *V. myuros* had germinated prior to June. By applying simazine in May or June there was little residual seed left to germinate following the degradation of simazine. However, by delaying application until July/August, *V. bromoides* and *V. myuros* plants had become larger and more resistant to the herbicide.

Moisture is required to activate simazine and move it into the root zone (Moyer 1987) where it will have the greatest effect on *Vulpia* spp. It is likely that there will be sufficient activating rains as early as April in many areas of southern Australia. The value of follow-up rains after a simazine application should not be ignored. There have been several instances of simazine failure which resulted from dry conditions soon after spraying (A. Wallace unpublished data).

The effective rate of simazine for *V. bromoides* and *V. myuros* control will vary with soil type (Stephenson 1990), since activity of simazine is related to soil organic matter content. The rate required to control *V. bromoides* and *V. myuros* plants on a soil high in organic matter will be higher than that required on a soil with low organic matter levels (Day *et al.* 1968, Rahman and Matthews 1979). Leys, Plater and Lill (1991) support the use of 0.75 kg a.i. ha⁻¹ on all but very light sandy soils that are low in organic matter. Wallace and Peirce (1993) recommend 0.375 kg a.i. ha⁻¹ for Western Australian conditions. Lower rates of simazine are less likely to damage *T. subterraneum* (Dowling 1984, Leys and Plater 1988, Madin 1989, Conlan *et al.* 1990).

Simazine may be mixed with grass selective herbicides (Leys and Plater 1993, Gameau and Dickinson 1994) or paraquat (Leys and Plater 1988, 1993) to give more complete grass control. Rates of simazine can be reduced with the addition of paraquat with no reduction in efficacy on *V. bromoides* and *V. myuros* (Wallace 1993, Gameau and Dickinson 1994). Rate of each chemical in the combination varies widely between studies (Table 2). Time of application was similar in all cases and efficacy on *V. bromoides* and *V. myuros* was in the same range in all three studies.

Simazine mixed with paraquat can damage *T. subterraneum*. *T. subterraneum* is scorched by the application of simazine plus paraquat and may suffer from a depression in growth for 2–3 weeks after treatment depending on rate applied. However, plants do recover with time (Leys and Plater 1993, Wallace 1993). Annual *Medicago* spp. are more severely affected than *T. subterraneum*.

Vulpia bromoides and *V. myuros* can be controlled by propyzamide (Madin 1989) and carbetamide (Code 1986, Stephenson *et al.* 1993). Rates of 1.75–2.1 kg a.i. ha⁻¹ carbetamide have been applied, resulting in successful control of both species. Mixes of carbetamide with simazine and paraquat have been investigated (Stephenson *et al.* 1993) with the aim of reducing the amount of carbetamide used to more economic levels. It was concluded that at least 0.7 kg a.i. ha⁻¹ of carbetamide was required to reduce *V. bromoides* and *V. myuros* to acceptable levels. At current prices (\$A34 per hectare) this rate would not be economic for broadacre agriculture.

Dalapon (2,2-DPA) is effective for the control of *Vulpia* spp. (D. Bowran personal communication). A rate of 1.48 kg a.i. ha⁻¹ has provided control *V. bromoides* and *V. myuros* without causing obvious damage to the annual *Medicago* spp. component.

Scott and Blair (1987) investigated the use of seed coatings for lucerne seed containing herbicides for the control of *V. myuros*. Of the wide range of herbicides tested, only EPTC (S-Ethylidipropylthiocarbamate) resulted in good control of *V. myuros* seedlings without damaging lucerne. Dalapon reduced dry matter yield of *V. myuros* but caused unacceptable damage to lucerne. This technique does not appear to be viable for controlling *Vulpia* spp.

Spray-topping. Spray-topping is the term given to the application of a sub-lethal rate of a non-selective herbicide (glyphosate or paraquat) to grass seed heads during flowering, with the aim of preventing viable seed set. *V. bromoides* and *V. myuros* can be controlled using the spray-topping technique (Blowes *et al.* 1984, Code 1986, Dear and England 1987, Kelso 1989).

Glyphosate appears more successful when applied slightly earlier during the flowering cycle than paraquat. Leys, Cullis and Plater (1991) applied glyphosate and paraquat each at two rates at heading, anthesis and early grain fill. When the density of *V. bromoides* was assessed in pasture the year following treatment, glyphosate was found to be the most effective if applied during heading/anthesis (at 0.27 kg a.i. ha⁻¹) and paraquat if applied at anthesis (at 0.2 kg a.i. ha⁻¹). These rates are nearly double those currently recommended.

Averaged over rates, times of application and the two years of the experiment, *V. bromoides* seed set was reduced by 65% (glyphosate) and 66% (paraquat) (Leys, Cullis and Plater 1991). Code (1986) achieved 69% control of *V. bromoides* using paraquat (0.1 kg a.i. ha⁻¹) applied in late spring. Kelso (1989) determined that the most effective application time for glyphosate and paraquat was at early head emergence. On average, a 70% reduction in the seed set of *V. bromoides* and *V. myuros* will result from spray-topping with glyphosate or paraquat. Considering the huge capacity for seed production exhibited by the two species (Jones and Whalley 1993), allowing 30% of seed to escape into the next year will not lead to an appreciable or rapid decline in *V. bromoides* and *V. myuros* populations. Seed production by *V. bromoides* and *V. myuros* can be further reduced by following spray-topping with grazing, which reduces the incidence of seed setting by post-spray regrowth.

Spray-topping increases the grazing value of *V. bromoides* and *V. myuros*, since crude protein (CP), water soluble carbohydrate (WSC) and organic matter digestibility (OMD) increase following spray-topping. Paraquat increased CP when applied at heading or anthesis. Glyphosate increased CP, WSC and OMD when applied at heading and sometimes also at anthesis (Leys, Cullis and Plater 1991). Improvement in quality of pasture after spraying may result in more thorough grazing of the pasture and hence greater reduction in seed carry over.

Crop situations. Simazine is effective against *V. bromoides* and *V. myuros* in a number of grain-legume crops. The rates applied, 1–1.25 kg a.i. ha⁻¹ pre-emergence, will control *V. bromoides* and *V. myuros*. However, Fua (1981) determined that at higher rates (1.8–2.4 kg a.i. ha⁻¹) simazine controlled *V. bromoides* and led to significant increases in lupin (*Lupinus angustifolius* L.) grain yield.

Oryzalin (0.29 kg a.i. ha⁻¹) plus trifluralin (0.29 kg a.i. ha⁻¹) and oxyflurofen at 0.25–0.72 kg a.i. ha⁻¹ were found to be ineffective against *V. bromoides* when applied to a lupin crop (Fua 1981).

Chlorsulfuron (0.015 kg a.i. ha⁻¹) plus trifluralin (0.4 kg a.i. ha⁻¹) is registered for *V. bromoides* and *V. myuros* control in Tasmania (Parsons 1992). However, as trifluralin must be incorporated following application it is likely that the cultivation, more than the herbicide, is reducing the incidence of *V. bromoides* and *V. myuros* in this situation.

Trifluralin (up to 0.84 kg a.i. ha⁻¹) provided acceptable levels of control of *V. bromoides* and *V. myuros* when applied to crops of lupins, field peas (*Pisum sativum* L.), canola, safflower (*Carthamus tinctorius* L.), linseed (*Linum usitatissimum* L.), chickpeas (*Cicer arietinum* L.) and faba beans (*Vicia faba* L.) (Leys et al. 1995).

Peirce and Rayner (1991) recorded significant reductions in *V. bromoides* and *V. myuros* density in a wheat crop where 0.13 kg a.i. ha⁻¹ glyphosate plus 0.025 kg a.i. ha⁻¹ trisulfuron was applied at crop establishment and followed up with treatments containing diuron (0.5 kg a.i. ha⁻¹) post seeding pre-emergence and post-emergence. Diuron was not applied alone in this experiment. Glyphosate (knockdown prior to seeding) with diuron at or immediately after seeding may be a useful combination for *V. bromoides* and *V. myuros* suppression in cereals. Diuron has been observed to lower populations of *V. bromoides* and *V. myuros* by 50% or more when applied at 0.5 kg a.i. ha⁻¹ early post emergence (D. Bowran, J. Peirce personal communication). This would only be useful in a salvage situation.

In field peas, cyanazine (1.5–2 kg a.i. ha⁻¹ pre-sowing, or 0.75–1 kg a.i. ha⁻¹ post-emergence) and metribuzin (0.135–0.280 kg a.i. ha⁻¹), pre-sowing or early post-emergence, suppress the growth and development of *V. bromoides* and *V. myuros* (Leys et al. 1995).

Other treatments

Cultivation. *V. bromoides* and *V. myuros* seeds are intolerant of burial (Dillon and Forcella 1984) and as a result are not able to recover if the seed bed is cultivated deeply. It is for this reason that *V. bromoides* and *V. myuros* have become weeds in cereal crops only following the introduction of the direct-drill technique (Amor and de Jong 1983).

In a survey of direct drilled fields *V. bromoides* and *V. myuros* were present at an average of 50.5 ± 78.8 plants per square metre (Forcella 1984). Only two of the conventionally tilled paddocks had *V. bromoides* and *V. myuros* present, at densities of 0.05 and 15 plants per square metre respectively (Forcella 1984).

Code (1986) reduced *V. bromoides* density by 80% (measured in spring) with cultivation during autumn. Remaining *V. bromoides* plants were subsequently removed (presumably by hand), and when the same treatments were applied to the

same plots in the following year, populations were 93–98% lower (Code 1986).

Plots ploughed in summer or early autumn had substantial numbers of *Vulpia* spp. seedlings (Forcella and Gill 1986) and alone it is not a recommended management practice for *Vulpia* spp. Tillage from March onwards reduced the number of seedlings. Provision of a stimulus such as shallow cultivation could encourage a higher proportion of seeds to germinate which could then be controlled by follow-up cultivation or an application of herbicide. The choice to use cultivation as a control method will depend on the land use of a particular paddock.

Grazing. *Vulpia* spp. can persist under heavy grazing (Rossiter 1966). When stocking rate was increased from 4.9 to 9.8 sheep per hectare, the proportion of *V. myuros* in the pasture increased. Cameron and Cannon (1970) observed a 30% increase in annual grasses, including *Vulpia* spp. when stocking rate was set at 4.9–12.4 wethers per hectare for six consecutive years. Increasing the stocking rate from 12.4 to 14.8 wethers per hectare, or greater, reduced the density of annual grasses to trace levels after six years (Cameron and Cannon 1970). Selective grazing by stock may lead to this outcome due to their preference for the more palatable species (Anderson 1979, Sharrow 1983). This factor could be a reason for the dominance of *Vulpia* spp. in degraded pastures in which the more palatable species have ceased to persist owing to high spot grazing pressure.

Retaining high stocking rates for long periods forces stock to graze all parts of a paddock and forage component equally, including the less palatable *Vulpia* spp. If stocking rate is not increased to compensate for seasonal growth flushes, patch grazing can occur, with sections of pasture becoming rank and under-utilized. The potential for *Vulpia* spp. to set seed in under-utilized patches would be higher than in heavier grazed areas.

Strategic grazing in spring (to reduce seed set) and autumn (to reduce seedling establishment) was investigated in New South Wales (Jones 1992, Jones and Whalley 1993). Heavy grazing in spring (100 DSE, 2 weeks on, 3 weeks off and 1 week on) reduced *V. bromoides* and *V. myuros* seed set significantly and, when combined with autumn grazing, the density of *V. bromoides* and *V. myuros* was reduced by 91–97%. Without spring or autumn grazing, large quantities of plant residue developed which impeded emergence of *V. bromoides* and *V. myuros* seedlings in autumn (Jones 1992, Jones and Whalley 1993). Reduced spring grazing also led to lower *V. bromoides* and *V. myuros* density due to competition with other pasture species.

Reliance on residues and competition with other species will be effective provided the pasture remains competitive and there is significant accumulation of dry matter. *V. bromoides* and *V. myuros* seed set is not impeded in spring and should the pasture density decline in future years, *V. bromoides* and *V. myuros* can re-establish a population from the residual seed bank.

Additional heavy grazing in autumn reduces pasture competition, forms bare areas and encourages recruitment of *V. bromoides* and *V. myuros* from the residual seed bank. Combining heavy spring grazing with autumn grazing proved the best option (Jones 1992, Jones and Whalley 1993). Heavy grazing in spring limits seed bank replenishment.

Integrated management. Because of the lack of chemical control measures for *V. bromoides* and *V. myuros* in non-legume crops, it is necessary to control these grasses during the pasture/legume phase of rotations. The following section deals with current results of integrated *V. bromoides* and *V. myuros* management involving chemical seed set control, cultivation and grazing.

Use of a herbicide (e.g. simazine) alone will result in only short term control of *V. bromoides* and *V. myuros* (Leys and Dowling 1992). Maintaining the pasture in a vigorous and healthy state will improve its competitive ability.

Increasing the density of subterranean clover in the pasture from 142 to 496 and 1846 plants per square metre reduced *V. bromoides* seed production by 51 and 77% respectively. Combining subterranean clover with annual ryegrass (677 + 778 plants per square metre) reduced *V. bromoides* seed production by 80% (Leys *et al.* 1992).

Maintaining a balance between subterranean clover and desirable pasture grasses is part of the solution. Where subterranean clover density alone is increased, *V. bromoides* and *V. myuros* rapidly reinvades. However, if a companion grass, e.g. *Phalaris* spp. or annual ryegrass, is included the rate of invasion is slowed (Leys and Dowling 1992, Leys *et al.* 1993). This agrees with Peart (1989b), who demonstrated the poor colonizing ability of *V. bromoides* in perennial grass swards. Peart (1989b) suggests that a continual, dense seed rain from a nearby source is required to maintain a population of *V. bromoides* in a perennial patch, indicating that *V. bromoides* is more likely to invade from the edges rather than the centre of a dense sward.

Simazine can be applied post-emergence to control *V. bromoides* and *V. myuros* in an annual ryegrass pasture post-emergence at rates of less than 0.5 kg a.i. ha⁻¹, with little damage to ryegrass.

Combining herbicides and timings may prove more effective than single applications. Pastures spray-topped (paraquat 0.1 kg a.i. ha⁻¹) in spring and followed by a June application of simazine (0.63 kg a.i. ha⁻¹) the next season controlled 85% of *V. bromoides* and *V. myuros* plants compared to 78% (simazine alone) and 46% (spray-topping alone) (Dowling *et al.* 1992).

Because spray-topping and heavy spring grazing (see above) are non-selective and will reduce the density of other grass species in the pasture, it may be necessary in some years to resow desirable grass species.

Controlling *V. bromoides* and *V. myuros* in the pasture for one to two years prior to cropping will minimize the amount of *V. bromoides* and *V. myuros* in the crop. Use of knockdown herbicides and cultivation will control early germinating *V. bromoides* and *V. myuros*. Seeding the crop at a competitive rate and applying adequate fertilizer will help suppress growth and seed production of any surviving plants. In-crop herbicides can also be used to aid control or suppression in most cases.

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