Why annual ryegrass is a problem in Australian agriculture

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Summary

Annual ryegrass (*Lolium rigidum* Gaudin) is a problem weed of cropping on most soil types found in southern Australia. Such widespread distribution is believed to be due to large genetic variability present in this species. Apart from successful adaptation to varying habitats, this attribute of the species has also enabled it to rapidly develop resistance to most of selective herbicides registered for its control. Herbicide resistant populations of *L. rigidum* are now found in all cropping regions of southern Australia. This paper presents information on the distribution of *L. rigidum* in Australia, conditions of its occurrence as well as ecological and habitat characteristics believed to be largely responsible for its success as a weed. Data on area infested and densities present on farms are scarce, making it impossible to accurately quantify economic impact of this weed on Australian agriculture.

Distribution

Annual ryegrass (*Lolium rigidum* Gaudin), the most important ryegrass in Australia, is found in all States and many offshore islands (Kloot 1983). Three species of this genus, *L. rigidum*, *L. multiflorum* and *L. perenne*, are wind pollinated outcrossers, with natural and bred hybrids between these three species also being found (Kloot 1983). Hereafter, unless otherwise indicated, annual ryegrass refers to *L. rigidum*.

Conditions of occurrence

Annual ryegrass is mainly a weed of crops and pastures, however it can also be found along roadsides and other non-agricultural situations. Mullett (1919), while highlighting positive features of ryegrass for sheep production, raised the possibility of this plant becoming one of the most serious pests in crops; prophetic words indeed.

Various ecological and habitat related characters which are likely to have contributed to the success of this species as a weed of agriculture are presented below. For additional information on the ecology of annual ryegrass, refer to the review on the subject in these proceedings.

Ecological factors contributing to weediness

High genetic variability

Genetic instability in this diploid and outcrossing species is likely to have contributed to its ability to rapidly adapt to a wide range of climatic and edaphic conditions (Kloot 1983). In a recent paper, Gill *et al.* (1996) have shown considerable differences in the rate of phenological development of annual ryegrass populations collected from different locations in Western Australia. The time taken to spike emergence in these populations was highly correlated with the latitude of the origin of the population, providing evidence for adaptation to the local climate since introduction. More southerly locations in the wheat belt of Western Australia generally experience a longer growing season.

Large seed production

Seed production of up to 45 000 seeds m^{-2} in a wheat crop has been reported (Rerkasem *et al.* 1980). In a grazed pasture, Gramshaw (1972) recorded annual ryegrass seed density of 20 000 seeds m^{-2}. Consequently, even with good pre-sowing weed control, a sizeable seed density is usually present at the time of sowing.

High plasticity

Annual ryegrass has an excellent capacity to tiller and exploit the available space. Surviving plants in a wheat crop can produce >1000 seeds m^{-2} (McGowan 1967). Davidson (1990) recorded an average seed production of 40 seeds $plant^{-1}$ in a wheat crop sprayed with chlorsulfuron and about 100 seeds $plant^{-1}$ from survivors of carbetamide in a lupin crop. Annual ryegrass can flower over a photoperiod of 8–24 hours. There is some verbalization requirement for flowering (Aitken 1966) which may be responsible for the uniformity of flowering usually observed in the field.

High seed survival over summer and autumn

Annual ryegrass seeds have short-lived innate dormancy which prevents germination with rainfall events in summer. Reported data indicate that normally, 40–80% of seed may produce seedlings at the break of season. The residual ungerminated, but viable, seeds (20–60%) are a major hazard to cereal yields if a crop is to follow (Gramshaw and Stern 1977). These results are consistent with those reported earlier by McGowan (1970).

Habitat characteristics contributing to weediness

Climate suitability

The genus *Lolium* is native to Europe, temperate Asia, North Africa and the North Atlantic islands. In addition to Australia, annual ryegrass is an important weed of wheat in France, Iraq, Portugal, Spain and Argentina. It is well adapted to the winter rainfall regions of all southern Australian states, which are characterized by hot and primarily dry summers and wet and relatively mild (no snow) winters.

Deliberately introduced over a large area

After research in the early 1900s, annual ryegrass was recommended for sowing in pastures in most areas of southern Australia. The combination of large scale introductions and high genetic variability in the species has allowed it to adapt to range of climatic and edaphic conditions encountered across the continent.

Relatively infertile soils with open crop canopies

The low fertility of Australian soils results in open crop canopies for a considerable period at the start of the growing season. This allows weeds to grow and reproduce successfully in the crop.

Frequent replenishment of the seed bank

Weed-free fallows are rare in Australia. During the pasture phase, most farmers still value early winter feed provided by annual ryegrass and it is usually controlled only in the year prior to cropping. This leaves a substantial residual seed bank to cause problems in the subsequent crop.

Short growing season

Over a large part of the southern Australian cropping zone, the growing season for crops varies from 6 to 8 months and there can be a substantial yield penalty for delaying sowing in order to achieve pre-sowing weed control. There is often a serious conflict of interest between utilizing maximum available moisture for crop production and achieving high germination of the weed seed bank. Consequently, crops are usually sown before most of the resident weed seed bank has germinated and a substantial germination takes place with, or soon after, crop establishment. Large farm size is another constraint on the farmers capacity to delay sowing.

High dependence on selective herbicides

For these reasons, Australian farming systems rely heavily on selective and non-selective herbicides for weed control.

The system is highly susceptible to the evolution of resistance in weed species. Some recent estimates suggest that over 0.5 million ha of the southern Australian cropping zone is already infested with resistant weeds and the area is rising rapidly every year. Although there are no data available, anecdotal evidence would suggest that the cost of annual ryegrass to Australian agriculture has increased substantially over the last 10 years due to widespread development of resistance to selective herbicides.

Disease host

Animal toxicity – annual ryegrass toxicity (ARGT)

ARGT is caused by ingestion of corynetoxins produced by a plant pathogenic *Clavibacter* sp. in the inflorescence of annual ryegrass. It is a serious animal health issue in all southern Australian states. An Australian Bureau of Statistics survey in 1989 determined there were some 900 affected farms in Western Australia alone, representing a 30% increase per year since 1968. An estimated 147 000 sheep and 500 cattle were reported lost over that period. Even where animal deaths are controlled, the presence of ARGT on a farm will usually lead to loss in pasture utilization, extra stock management and considerable anxiety for the farmer. Stock mortality has also been high in South Australia, with more than 8000 sheep deaths reported from 1955 to 1982 (McKay 1990).

Control of ARGT is largely dependent on the control of its host and development of herbicide resistance in annual ryegrass has been shown to exacerbate the problem (Riley and Gill 1994).

Animal toxicity – ergot

Ryegrasses are quite susceptible to ergot fungus (*Claviceps purpurea* (Fr.) Tul.) under field conditions. In Western Australia the problem appears to be confined to high rainfall coastal regions where it is not uncommon to have ergot contamination in wheat and barley grain. This can lead to downgrading of grain because ergot fungus is toxic to man and animals (Burgess *et al.* 1990).

Cereal diseases – take-all

Ryegrasses are thought to be susceptible to the take-all (*Gaeumannomyces graminis* (Sacc.) von Arx & Oliv.) fungus (Cotterill and Sivasithamparam 1988), but the evidence is meagre (Burgess *et al.* 1990). While annual ryegrass can be artificially inoculated with *G. graminis*, there are no reports in the readily accessible literature of pathogenicity under natural conditions, or of the isolation of the fungus from field-infected plants (Burgess *et al.* 1990). There is an obvious need to clarify the susceptibility of annual ryegrass to take-all, and the contribution that infected annual ryegrass makes to the inoculum levels in the soil.

Crop/pasture losses

Competitiveness of annual ryegrass in Australian crops has been the subject of several published investigations, which have been summarized by Gill (1996).

In pastures, it is generally valued for its winter feed production. Morrison and Bathgate (1990) calculated the value of early winter (May–July) feed at \$0.2 kg^{-1} as compared to \$0.02 kg^{-1} for feed in spring when pasture is plentiful. Grasses, in particular annual ryegrass, have been shown to increase early season pasture production. Nevertheless, having annual ryegrass in pasture means less nitrogen fixation, risk of stock losses due to ARGT and reduced cereal production due to weed competition.

Costs

There are very few published data available on the extent of infestation of crops by various weed species. However, data from two such surveys in Victoria (Wells and Lyons 1979, Amor and Gagen unpublished data), were used by Code (1990) to derive the cost of annual ryegrass to Victorian agriculture. Combining yield loss due to competition with crops and expenditure on selective herbicides, Code (1990) reported an annual loss of \$37.4 million in that state alone. This represented 7.9% of the total farm-gate value of grain produced in 1987. Using the data of Code (1990) and the 1992 / 93 grain production in Western Australia, the author calculated the annual cost of annual ryegrass to growers in that state to be \$117 million. While considerable errors could exist in calculating these figures, due to incomplete data for Victoria and the absence of data for other states, they are a guide to the magnitude of the costs incurred.

Future research/activities

- Determine / survey magnitude of weed problems on farms in southern Australia in order to gauge the success of the CRC programs (research and adoption) for annual ryegrass management.
- Clarify status of annual ryegrass as a host for take-all (not necessarily a CRC activity).

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Ecology of annual ryegrass

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Summary

Annual ryegrass (*Lolium rigidum* Gaudin) is a major weed of cropping in southern Australia. It is a prolific seed producer and figures as high as 45 000 seeds m^{-2} have been reported. *L. rigidum* seeds have a short period (about two months) of innate dormancy. A proportion of the seed bank can have dark-dormancy which has been suggested as a factor contributing to short term persistence of buried seeds of *L. rigidum* in crop-pasture rotations. Seed by environment interactions allow a large proportion of the seed bank to survive until well after crops have been sown. Depending on its density and time of emergence, *L. rigidum* can be highly competitive with the crop and the competition can start as early as the two-leaf stage of the crop.

Introduction

Annual ryegrass (*Lolium rigidum* Gaudin) was sown in pastures (and even undersown in crops) over large areas of southern Australia. Kloot (1983) documented occurrence of this species in all Australian states and on many off-shore islands. *L. rigidum* is an outcrossing diploid (2n=14) whose wide adaptability and variable morphology arise from its genetic instability (Cariss 1962, Kloot 1983). *L. rigidum* is arguably the most important weed of agriculture in Australia, infesting crops on a wide variety of soil types and climatic conditions. Millions of dollars are spent annually on herbicides for *L. rigidum* control. An estimate in 1989 indicated that in excess of $33 million was spent on herbicides for *L. rigidum* control in Western Australia alone (Madin personal communication).

This paper will review different aspects of the ecology of *L. rigidum* that makes it such a successful weed of field crops in southern Australia. The biology of the weed was last reviewed by Monaghan (1980) and the major development since then has been the evolution of resistance in *L. rigidum* to a range of selective herbicides (Powles and Howat 1990, Gill 1995).

Seed production

There are few published data on the fecundity of *L. rigidum*. Rerkasem *et al.* (1980a), under irrigated conditions, reported seed production figures of 31 000–45 000 seeds m^{-2} when growing in a wheat crop. Davidson (1990) recorded *L. rigidum* seed set of nearly 26 000 seeds m^{-2} in an ungrazed pasture but a combination of heavy grazing in spring and spray-topping with paraquat caused a 92% reduction in the seed production of *L. rigidum* (2000 seeds m^{-2}). *L. rigidum* sprayed with selective herbicides in wheat and lupins still managed to produce 2500–9000 seeds m^{-2} (Davidson 1990). Although this might be substantially lower than the unsprayed controls, it is still high enough to cause problems in the following crop and lock the farmer into using selective herbicides every year.

Seed dormancy and germination

As in most other grass species of Mediterranean origin, *L. rigidum* seeds are dormant at the time of production although this period of innate dormancy is fairly short. Gramshaw (1972) reported a rapid alleviation of seed dormancy within nine weeks of harvest.

Gramshaw (1972) also failed to detect any significant differences in seed dormancy after 18 weeks storage, between eight accessions of *L. rigidum* grown at two common sites. However, the accessions differed significantly in their level of dark dormancy (7–22% range). Subsequent studies of Gramshaw and Stern (1977b) showed that the dark-dormant component can be substantial, at 10–20% of the total seed population. This component of the *L. rigidum* seed bank may be important in short term field persistence of seeds buried in the soil.

Burial of *L. rigidum* seeds by cultivation can affect their germination and establishment. Smith (1968) and Pearce and Quinlivan (1971) found optimum germination and seedling emergence (70-90%) from *L. rigidum* seeds buried near the surface of the soil, at about 2 cm depth. Gramshaw and Stern (1977b) also reported a decrease in the germination of *L. rigidum* with increasing burial depth, with complete inhibition at 11–14 cm. However, these seeds germinated readily when brought up to a depth of 2 cm without soil disturbance. This indicated enforced dormancy possibly due to an unfavourable gaseous environment in the deeper soil layers.

Like other plant species, germination in *L. rigidum* is highly responsive to temperature. Under constant temperature regimes, Gramshaw (1976) reported a sharp increase in the rate of germination with increase in temperature from 8–26°C and a slight reduction in the rate with further