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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 temperature increases to 35°C. Optimum temperature for the germination of after-ripened seeds of *L. rigidum* is different in light and dark; in the light the optimum was 27°C, whereas the optimum in the dark was much lower at about 11°C (Gramshaw 1976). Furthermore, germinability of *L. rigidum* seeds at alternating temperatures in darkness has been shown to depend solely on the lower temperature (Gramshaw 1976). In contrast, light and alternating temperatures appeared to interact to increase germinability, although the highest germinability occurred only when the maximum temperature was close to the optimum constant temperature, i.e. 27°C (Gramshaw 1976). The lower temperature requirement for germination in the dark is likely to reduce depletion of the buried seed bank of *L. rigidum* following rainfall events in summer.

Rainfall events during late summer and autumn also have a major influence on the germination behaviour of *L. rigidum* and possibly, on the success of pre-sowing control measures. In the cereal belt of Western Australia, one or two substantial falls of rain (some 10 mm or more) commonly occur in summer to early autumn. Such rainfall events, although insufficient to cause germination, do nevertheless markedly increase the potential germination rate of *L. rigidum* seeds (Gramshaw 1972, Cocks and Donald 1973). Later studies of Lush *et al.* (1981) showed that a single hydration-dehydration cycle approximately doubled the speed of germination of *L. rigidum* by shortening the lag phase of germination. In years with a relatively dry summer and autumn, germination of *L. rigidum* before seeding may be quite low and protracted.

## Seedling emergence in the field

McGowan (1970) recorded successive germination of *L. rigidum* during autumn and early winter in an undisturbed pasture and also when the surface soil was cultivated. Measurements in two seasons showed that 75–80% of the total seasonal germination had occurred after the first two substantial falls of rain (>20 mm) at the beginning of the season. Residual viable seed under the undisturbed pasture in late winter, represented less than 1% of the total seasonal germination. There appeared to be short-lived dormancy in the seed population and this could be a significant factor in the survival of some seed through cultivations prior to cropping in the cereal-pasture rotation.

The grazing history of paddocks over summer was found to influence the germination of *L. rigidum* after the opening rains in autumn; more seeds germinating in pastures which were heavily grazed (Gramshaw and Stern 1977a). Heavy grazing reduced the amount of seed firmly held in seed heads and at break of season, this component of *L. rigidum* seed was found to germinate more slowly than seeds shed to the soil surface (Gramshaw and Stern 1977a). Even in a cropped paddock, a considerable proportion (16%) of ryegrass seed can still be attached to broken segments of seed heads (Gill unpublished data). Swathing the crop a few weeks earlier reduced this component of ryegrass seed bank to 4% of the total.

According to Gramshaw and Stern (1977a), seedling emergence of *L. rigidum* in autumn is regulated mainly by the interrelationship between the germination rate of the seed population, the occurrence of summer / early autumn rains, and the period for which favourable moisture conditions prevail at the soil surface after rains begin in autumn. In the field, temperature and light appear to be relatively unimportant in influencing germination at the break of season.

In the field, *L. rigidum* appears to have a protracted emergence pattern. Farmers generally do not view delaying sowing as an effective strategy against *L. rigidum*. It is possible that due to its prolific seed production capability, a substantial density of seed is still present even after a large proportion of the seed bank has been exhausted by germination prior to sowing. As McGowan (1970) found, 12–23% of seasonal germination of *L. rigidum* seed occurred after June, by which time most crops would have been sown. The logistics of sowing programs on large farms are such that most farmers would not be prepared to wait this long to achieve better weed control. Furthermore, missed early sowing opportunities, just to control *L. rigidum*, can result in large loss of income in some seasons.

Tillage regime of the seed-bed can also influence the germination pattern of weed seeds. Davidson (1994) reported a faster rate of *L. rigidum* emergence in plots that received no cultivation as compared to plots cultivated with various tyne and disc implements. These results contradict those of Smith (1968), who had earlier reported a faster rate of germination of *L. rigidum* when seeds were covered with soil as compared to those on the soil surface. Gill (unpublished data) showed large effects of different tillage treatments on the establishment of *L. rigidum* in wheat on a sandy loam soil in Western Australia. All treatments that received cultivation, either before sowing or with the sowing operation, showed much faster and greater final emergence than the uncultivated plots. There was also an indication of greater weed seed carryover in undisturbed plots. With the growing trend towards no-till farming, it is important to investigate the ecology of *L. rigidum*, and other important weeds, under different tillage regimes.

## Phenology

According to Aitken (1966), the major influence on the rate of development of *L. rigidum* was a cold requirement (vernalization) for flower initiation. Plant development was most rapid after sowing in the cooler part of the year, when time to heading was only one-half to one-third as long as when sown in summer. In an earlier study in Adelaide, Silsbury (1964) also showed that the heading (spike emergence) of *L. rigidum* was related mainly to the response of various cultivars to the cold treatment. Long photoperiod has also been shown to hasten the rate of development of *L. rigidum* plants, both before and after flower initiation (Aitken 1966). The winter level of photoperiod delayed flower initiation even if seed was vernalized before sowing in winter. Because of its short cold requirement and low critical photoperiod, *L. rigidum* is well suited to the short and variable growing season of the wheat belt (Aitken 1966).

## Crop-weed competition

*L. rigidum* can cause large yield losses in wheat (Poole and Gill 1987). In a heavily infested crop, *L. rigidum* can compete with wheat for nitrogen as early as the two-leaf stage of crop growth (Smith and Levick 1974). Time of sowing can have a marked effect on the competitive ability of *L. rigidum* in wheat (Reeves 1976a), with later sown crops suffering a greater percentage loss in yield.

Rerkasem *et al.* (1980a) used the replacement series of de Wit, and concluded that increasing the density of wheat does little to overcome the effect of *L. rigidum* competition on the yield of wheat. Such a result is however, contrary to the conclusions of Medd *et al.* (1985), who suggested increasing crop density as a means for reducing competition from *L. rigidum*. Our unpublished data from Western Australia over the last two growing seasons has also shown considerable benefits of increasing crop density on the grain yield of wheat and reduced shoot biomass and seed production of *L. rigidum*. Altering the spatial arrangement of the crop however, did not have a significant impact on competition with *L. rigidum* during a three year study in central western New South Wales (Medd *et al.* 1985).

Time of emergence and establishment of *L. rigidum* relative to the crop is also likely to be important in determining the outcome of competition between the two species. Rerkasem *et al.* (1980b) found the competitive ability of *L. rigidum* to be low when it germinates later than wheat.

In a preliminary investigation, Reeves (1976b) failed to detect any difference between four wheat genotypes in their competitive ability against *L. rigidum*. Subsequently, however, Reeves and Brooke (1977) reported differences between wheat cultivars in their ability to compete with *L. rigidum*, but they could not correlate this with differences in height, tillering or dry matter accumulation between the varieties. Later, Lemerle *et al.* (1979) showed triticale (*Triticum* × *Secale*) to be less sensitive to competition from *L. rigidum* than wheat. Poole (1979) compared barley and wheat for competitiveness with *L. rigidum* and found that barley was affected less than wheat at equivalent densities of the weed. More vigorous tillering and prostrate growth habit of barley may explain the difference.

Reeves (1976a) reported a consistent relationship between *L. rigidum* density and yield loss in his trials and suggested that it was possible to predict yield loss in *L. rigidum* infested crops. Gill and Poole (1986) found some evidence to suggest that prolonged dry soil surface conditions after seeding may retard establishment of *L. rigidum* relative to wheat and therefore reduce its competitive effect on the crop. Such dry conditions are not uncommon in barley growing areas of Spain where *L. rigidum* seedlings in some seasons established 3–4 weeks after the crop resulting in little or no detectable yield loss (Izquierdo personal communication).

Narrow-leaf lupins (*Lupinus angustifolius*) are also affected by competition from *L. rigidum*. Allen (1977) reported large yield reductions in lupins from *L. rigidum* emerging before and with the crop. *L. rigidum* seeds continued to emerge as late as six weeks after the crop, but were not competitive with the crop and failed to cause any yield reduction (Allen 1977). In a later study, Arnold *et al.* (1985) also found *L. rigidum* to be highly competitive with lupins. Ryegrass density of 39 plants m$^{-2}$ was found to reduce lupin grain yield by 15%. In this study of Arnold *et al.* (1985), lupin biomass production was unaffected by ryegrass until October and reduction in yield appeared to be due to lower pod-set on the main stem and lateral branches. It is possible that ryegrass was competing with lupins for available soil moisture or the lower pod-set could also have been due to shading of lupins by ryegrass.

Weed density-yield loss relationships are guides to assist on-farm decision making. Economic threshold density of a weed is not a single fixed value; it can vary considerably due to changes in factors such as grain yield, price of grain and cost of weed control. Consideration of weed infestations in the future and costs incurred to control them, can further reduce the threshold weed density. Therefore, efforts to fine-tune weed density-yield loss relationships to the last kilo are not likely be rewarding.

## General discussion

In spite of its short innate dormancy, a substantial fraction of the *L. rigidum* seed bank can persist until the break of season. Reported data indicate that between 40 and 80% of viable seed may produce seedlings at the break of season (Gramshaw and Stern 1977a). The residual ungerminated (but viable) seeds (20–60%) may cause major reductions in crop yields, especially when seed banks are large.

The inability of all viable seeds to germinate at the break of season may be attributed partly to the presence of intact seed heads, particularly in pasture that has been leniently grazed in spring and summer, and partly to the moisture status of seeds that are in contact with the soil. Gramshaw and Stern (1977a) found that, at the break of season, soil moisture was sufficient for only 2–3 days during the seasonal breaks monitored, and this clearly precluded germination of some seeds. Even in cropped paddocks, it is common to find segments of spikes on the soil surface after the harvesting operation. This component of the seed bank may be partly responsible for extending the period of germination of *L. rigidum* seeds after the break of season.

## Future research

- Germination, emergence and persistence of the *L. rigidum* seed bank under different tillage regimes.
- *Lolium rigidum* seed management at harvest – seed capture, how can it be improved e.g. swathing, header trail management (burning, non-selective spray with a single nozzle boom).
- Seed-shedding in *L. rigidum* – genetic variability.
- Improving crop competitiveness – cultivars, agronomy.
- Other non-chemical techniques to minimize seed production/input into the seed bank.

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# Cultural management of annual ryegrass

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## Introduction

The availability of both selective and non-selective herbicides during the last twenty years has provided a range of herbicides to manage ryegrass in crop and pasture paddocks with a consequent decline of alternative management strategies. However, strategies for the management of annual ryegrass (*Lolium rigidum* Gaudin) without the use of herbicides have been re-focused in the last decade by the appearance of populations of annual ryegrass that are not controlled by the use of selective herbicides. Annual ryegrass is widely distributed across the southern Australian cropping regions (Mayfield and Edwards 1992) as are the sites with herbicide resistant populations (Nietschke *et al.* 1996, Gill 1995, Pratley *et al.* 1993). Changes in cropping systems, namely, increased fertilizer use, different crop varieties and crop species along with minimum tillage systems have accentuated the development of herbicide resistance in annual ryegrass. Cultural methods of ryegrass management have become important for the prevention and management of herbicide resistance in ryegrass. This review of the cultural management of ryegrass assumes that herbicide resistant ryegrass is similar to susceptible ryegrass in germination, growth and seed output (Gill *et al.* 1996, Matthews unpublished data).

## Ryegrass management in pastures

### *Grazing*

Ryegrass is usually reduced in density by grazing over a number of seasons. The seed heads are preferentially grazed by sheep and cattle and seed return to the paddock is thereby reduced. The grazing intensity needs to be high to effect a net reduction in seed return in any one season (Pearce 1975). With insufficient grazing pressures other grasses *viz. Vulpia* spp., *Hordeum* spp. and *Bromus* spp. will increase due to the unpalatability of seeds from these species. Grazing alone has been largely superseded

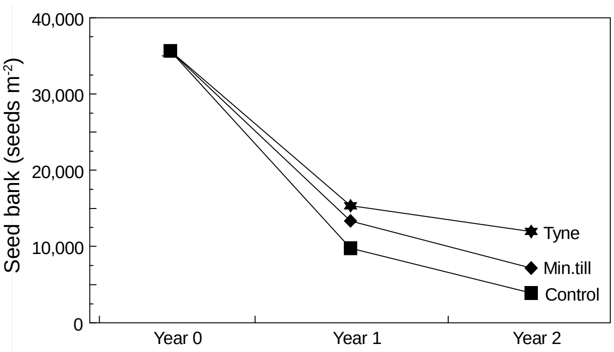

**Figure 1. Comparison of seed bank decline attributed to tillage method at sowing and compared to a no cultivation control (redrawn from Davidson 1994).**

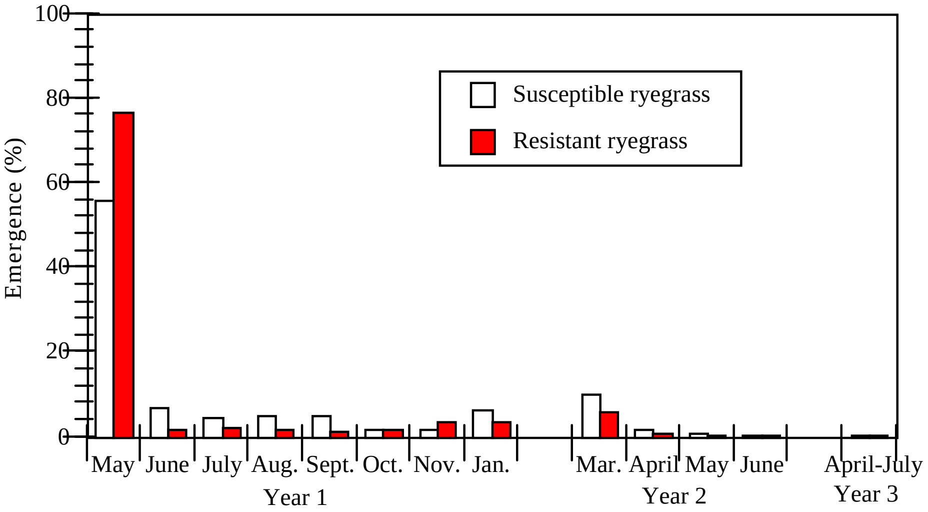

**Figure 2. Emergence of susceptible and herbicide resistant ryegrass over a three year period, from Heap (1988).**