Aspects of the population dynamics of selection for herbicide resistance in *Lolium rigidum*.(Gaud)

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Summary

The selection of herbicide resistant annual ryegrass populations in the cereal growing regions of southern Australia has been rapid. Ryegrass populations that have not been exposed to herbicides obtained from farms in this region exhibit a level of resistance indicative of polymorphic gene frequencies. A low frequency of individuals from non-farm populations tolerate lower rates of herbicide only. The frequency of resistant plants is sufficient to cause a rapid increase in numbers of resistant plants if a selection pressure is applied. The dominant inheritance of factors causing resistance and cross-resistance can quickly increase the resistant phenotype in ryegrass populations. Two applications of diclofop methyl selected for resistance to the selective chemical and cross-resistance to two other unrelated herbicide groups. The outcome of variable selection pressure applied to a variable gene pool for resistance is a complex range of resistance patterns. Management of resistant populations will be complicated and population specific.

Introduction

The diploid, cross-pollinated grass, annual ryegrass is the most important grass weed of cereal and grain legume crops throughout southern Australia. It has a wide range and is often present at high numbers in the crop phase (1). Selective herbicides are widely and persistently used for annual ryegrass control (2). This practice has resulted in the appearance of resistant biotypes at many locations throughout southern Australia. Currently we estimate there are about 800 infestations of herbicide resistant biotypes of annual ryegrass. Many of these have developed resistance due to the use of the herbicide diclofop-methyl. They also exhibit resistance to many other selective herbicides of both similar and dissimilar chemistry. Control of annual ryegrass in cereal and grain legume crops with post-emergent selective herbicides can become ineffective with continuous use. All annual ryegrass biotypes remain susceptible to the non-selective herbicides paraquat and glyphosate.

Frequency of resistance.

We have indentified a frequency of 0.02 ± 0.0092 (S.E) of plants displaying resistance in previously unsprayed farm populations of ryegrass across southern Australia (Table 1). Populations were established in pots and screened at the field rate of diclofop methyl. Populations tested from non-farm sites had little detectable resistance (< 0.002) when tested at the same rate. The frequency of resistant plants indicates that the factors conferring resistance are at a polymorphic frequency in unsprayed farm populations and substantially less in non-farm populations. There may be several explanations for this observation. The characteristics of pollen spread in transferring resistance genes is largely unknown, however the increasing incidence of herbicide resistance may provide enough sources of pollen to account for the difference between farm and non-farm gene frequencies. Also the populations may not be fertile at the same time.

Table 1. Frequency of resistant plants in unsprayed populations of ryegrass when exposed to diclofop methyl. (n.d. not determined)

Population source	Survival at 1l ha⁻¹	Survival at 0.75l ha⁻¹	Survival at 0.5l ha⁻¹
On farm	0.02 ± 0.0092	n.d.	n.d.
Non farm	0	0.0092 ± 0.0015	0.0107 ± 0.0021

Secondly, normal farm practices such as grazing or fertilizer application may impose a positive selective pressure on populations for genes that are linked to or confer resistance.
We conclude that genes conferring resistance are at a frequency sufficient to cause a rapid shift to resistance if a sustained selection pressure by herbicide application is applied.

Rate of selection for resistance.

The selection pressure for resistance in the field is obviously variable but can be high due to the effectiveness of recently released herbicide groups. The combination of frequent or continuous herbicide applications and a high effective kill rate, results in an extremely high selection pressure being applied to weed populations. Another factor contributing to rapid selection of resistance is the number of weeds per unit area exposed to a herbicide. The more plants of a variable population treated with an effective herbicide the higher the probability of selecting resistant individuals.

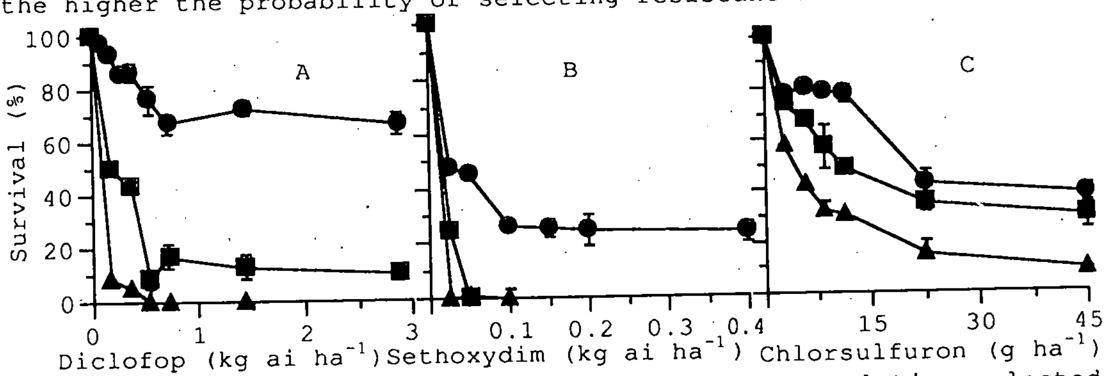

Figure 2. Graph of the response of a susceptible population selected for two generations with the field rate of diclofop methyl, when screened with three herbicides. Parent generation (▲), F1 generation (■), F2 generation (●). Figure 2A screened against diclofop methyl, 2B sethoxydim and 2C chlorsulfuron.

Resistance genes can rapidly accumulate in response to selective pressure. Figure 2A describes a three-fold change in LD75 for each generation. This is consistent with the high, but incomplete dominance of inheritance of the factors causing resistance in individual plants (Matthews and Tardif unpublished). The selection for cross-resistance (Figure 2B, 2C) is also strong, although appears to lag by about one generation. An interesting feature of the selection process is the appearance within the population of a subset that are largely unaffected by increasing rates.

The strong directional selection is ameliorated in the field only by susceptible plants germinating from seed in the soil. It appears inevitable that sustained use of selective herbicides will generate more cases of resistance and cross-resistance.

Resistant populations are not the same.

Control of herbicide resistant ryegrass is complicated by the range of and the variability of the response to herbicides that are registered for use on ryegrass. Figure 3 shows two populations which have been selected by different herbicide regimes. The outcome of the selection process is different in each case, the percentage kill at the field rate and the range of useful herbicides are different.

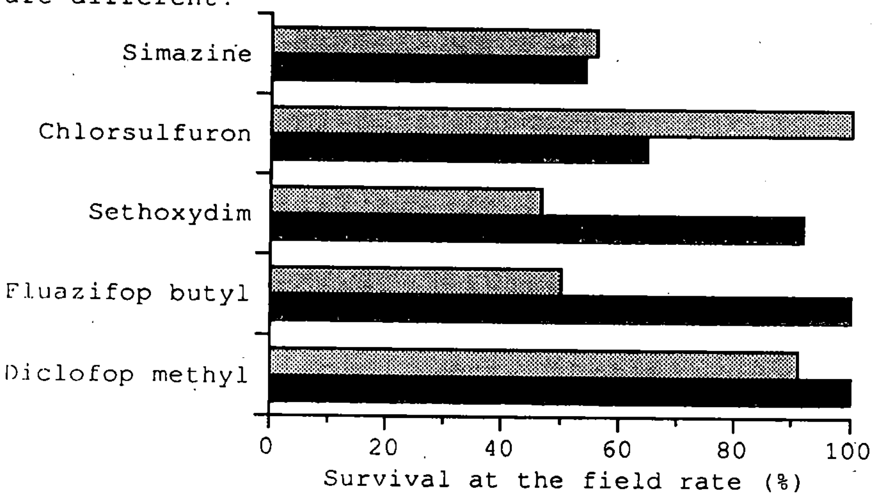

Fig. 3. Response of two populations to herbicides. ▒ selected by five applications of sethoxydim. ■ selected by seven applications trifluralin, two each of diclofop methyl and sethoxydim.

The composition of and initial frequency of genes conferring resistance (3), and the variability of the selection process all contribute to the different patterns of resistance. We are also observing the populations at a discrete point in time and further development of resistance may occur, however the resistance to diclofop methyl is well developed in each biotype. The management of resistant populations in the field is made more complicated by the observed variability. Control of herbicide resistant annual ryegrass is possible only by integrating cultural practices, rotational non-crop phases and judicious chemical applications of effective herbicides.

References.

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