FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

UA00060

Developing management systems for brome grass, a serious threat to production systems on fragile sandy textured soils in southern Australia

PROJECT DETAILS

PROJECT CODE:	UA00060
PROJECT TITLE:	DEVELOPING MANAGEMENT SYSTEMS FOR BROME GRASS, A SERIOUS THREAT TO PRODUCTION SYSTEMS ON FRAGILE SANDY TEXTURED SOILS IN SOUTHERN AUSTRALIA
START DATE:	01.03.2003
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Summary

Brome grass is a serious threat to crop productivity on sandy textured soils in southern Australia. As a consequence of the project UA00060, vital information has been obtained on the seedbank ecology and population dynamics of brome in response to various management strategies developed through on-farm research. Rotations that incorporate broadleaf crops with Clearfield™ wheat and barley were found to be effective in driving down the populations of this weed. The studies showed that the brome seedbank can persist for three years, which would make it necessary for growers to prepare a long-term management strategy for this highly aggressive weed species.

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Conclusions

1. Results from the survey of grower paddocks on Yorke (YP) and Eyre Peninsulas (EP) in South Australia (SA) confirmed the species of brome grass infesting cereal crops of southern Australia as *Bromus diandrus* and *Bromus rigidus*. However it was clearly evident that *B. rigidus* is the dominant species of brome, particularly on Eyre Peninsula, where it was found in-crop at every site surveyed.
2. Studies undertaken showed that *B. rigidus* had strong seed dormancy which was under hormonal control and germination was inhibited by light. Treatment of seed with gibberellic acid#, vernalisation (cold stratification) or potassium nitrate# significantly increased germinability. These responses go some way to explaining the behaviour of *B. rigidus* in the field and its possible proliferation under no-till. Under no-till, seeds of *B. rigidus* remain un-germinated on the soil surface exposed to light until sowing of the crop, resulting in more seedlings emerging in-crop. Furthermore, stimulation of seed germination by vernalisation could play an important role in restricting germination and seedling emergence to autumn-winter period when probability of seedling survival in this environment is the highest. The results also suggest that broadcast application of nitrogenous fertilisers (i.e. urea (U)) in the field could stimulate germination of *B. rigidus*. The germination behaviour of *B. rigidus* observed in these studies is expected to contribute to seed-carry over from one season to the next and favour its colonisation of crops as reported in the field survey.
3. Data collected on the residual seedbank of brome showed that carry-over from one season to the next can be as high as 30%. Furthermore, this level of persistence was not confined to non-wetting soils. Studies undertaken to determine the longevity of brome seed also showed that two to 7% of seeds can remain viable in soil after two years. This effectively means that to exhaust all viable seeds in the soil a period of three years of complete control is required to prevent reinfestation.
4. The project clearly identified that crop rotations combining either a legume (vetch or lupins) or pasture phase with Clearfield™ wheat and barley, which provide an opportunity for applying herbicides most effective against brome, resulted in successful depletion of the seedbank. The underlying success in depleting the seedbank depends on achieving two to three consecutive years of management.
5. Best option for controlling brome in the cereal phase is the use of imidazolinone# herbicides in Clearfield wheat. Issues concerning the lack of varietal choice, cost of herbicide and residual persistence in the field will limit adoption of this technology. Attempts to control brome in wheat with mixtures of trifluralin# and Logran®# were generally unsuccessful and resulted in significant increases (three to five-fold) in the brome seedbank. Applications of herbicides Atlantis®# or Monza®# provide some control of brome in conventional wheat, however these herbicides at best provide suppression rather than complete kill.

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6. Metribuzin# remains a useful option for controlling brome in barley and may provide a cost-effective alternative to Clearfield wheat when used in wheat cultivars tolerant to the herbicide. Tolerance in the wheat cultivar Blade⦶ appears to be derived from the parental line Kite. Further developments in breeding and screening will lead to release of tolerant material with high yield potential.

Recommendations

1. Considering the persistence of the brome seedbank, growers need to focus on controlling this troublesome weed over consecutive seasons in order to deplete seed reserves. To effectively do this, crop rotations that ensure a two to three-year phase of a high level of control are required. A rotation that combines either a legume (vetch or lupins) or pasture phase with Clearfield™ wheat and barley will allow the best sequence of herbicide options to be used. In the legume and/or pasture phase best control is obtained when both a grass selective herbicide (Verdict®# or Targa®#) and spray-top operation (Gramoxone®# or glyphosate#) are undertaken. Results from on-farm studies clearly showed that growers who relied solely on spray-topping were less successful in preventing seed set and seedbank depletion.
2. Although the exact mode of seed decline was not investigated here, it was evident that germination was mainly responsible for seed loss of brome. Consequently, to enhance seedbank depletion, conditions favourable to germination are required. This may involve performing a shallow autumn tickle to remove the inhibitory effect of light, or on light non-wetting soils, spreading clay to improve the soil's capacity to remain moist so seeds can more readily imbibe and germinate on the season break. Promotion of earlier and larger cohorts of brome can then be more effectively controlled prior to sowing using knockdown herbicides. This will help reduce the number of seedlings that can potentially germinate in-crop.
3. Use of imidazolinone# herbicides in Clearfield wheat provide the best opportunity to control brome in the wheat phase. However, over-use of this technology and fragile group B herbicides may lead to an increase in herbicide resistance in weeds. This technology should therefore be used in conjunction with an integrated weed management (IWM) program to prolong its usefulness. Populations of brome resistant to the sulfonyl-urea (SU) herbicide Monza®# (sulfosulfuron#) were recently identified (pers. comm. P. Boutsalis), highlighting the need for caution.

Outcomes

The expected outcome from this project was the development of improved management strategies for the control of brome grass which is a serious constraint to the adoption of more sustainable and profitable farming practices. Brome grass has significantly reduced adoption of conservation tillage and continuous cropping due to grower concerns about the weed's proliferation and difficulties associated with its control with these practices. In crops and pastures this competitive weed can significantly reduce productivity, with seeds contaminating grain samples and causing injury to livestock.

Project findings have greatly improved our understanding of the behaviour of this weed in the field. More specifically, important information was obtained concerning the ecology and population dynamics of brome.

Prior to this project there was considerable confusion amongst growers, consultants and researchers about the identity of the species of brome infesting cereal crops of southern Australia. Following a survey of brome in grower fields on Yorke and Eyre Peninsulas it was apparent that *B. rigidus* was the more problematic species of brome grass. Studies undertaken on *B. rigidus* showed that it was more reluctant to germinate in the field with greater expression of seed dormancy with un-germinated seeds contributing to a more persistent seedbank (two to three years). Seed germination of *B. rigidus* was also shown to be strongly inhibited by light. The slow germination pattern of *B. rigidus* allows it to evade early control measures, contributing to greater infestation in crops.

Information on the behaviour and persistence of brome has led to the development of management strategies that provide effective control of this troublesome weed. These strategies were developed on the basis that:

a. they provide consecutive years of control as required for seedbank depletion,
b. they maintain sustainable productivity and income by maintaining a focus on crop productivity and
c. allow growers to pursue more sustainable farming practices (i.e. no-tillage) and their benefits without compromising on weed management.

As a consequence of this project our increased understanding of the behaviour of brome has enabled the development of successful management strategies that should enhance confidence in southern Australian grain growers to adopt more sustainable cropping practices without compromising on weed management, productivity and profitability.

Achievements/Benefits

Brome grass has effectively naturalised in southern Australia becoming more problematic in the region because of an increased frequency in cropping, adoption of conservation tillage, and lack of effective herbicides for selective control in wheat. Farmer concerns about the inability to control this problematic weed were raised at several GRDC Updates and grower meetings, leading to the initiation of project UA00060. The project has addressed our lack of understanding of the behaviour and population dynamics of brome and has provided findings for the development of effective management strategies.

Survey of brome grass in South Australia

The project activities started in 2003 with a quantitative survey of farmer paddocks on Yorke and Eyre Peninsulas. The aim of the survey was to identify the species of brome grass infesting cereal crops of South Australia. The random survey undertook a census of 40 grower paddocks from which 40 mature heads of brome were sampled for species identification. This was undertaken by morphological (callus scar) features of brome seed and cytological (somatic chromosome number) assessments performed on the root tips of young brome seedlings. The survey identified three species of brome common to the different agro-ecological zones: *Bromus diandrus, Bromus rigidus* and *Bromus rubens*. The results clearly showed the preference of *B. diandrus* and *B. rubens* to inhabit undisturbed fence-lines in contrast to *B. rigidus*, which was found to dominate in-crop. The dominance of *B. rigidus* was particularly evident on EP, where it was found in-crop at every site surveyed. These findings clearly show that *B. rigidus* is well adapted to this environment, possessing characteristics of ecological value that allow it to evade control. Furthermore, these findings provided clarity to previous work performed in the mid 1980s at a time when taxonomists were in disagreement as to whether *B. rigidus* was in fact present in Australia.

On-farm trials

The next phase of the project involved the establishment of farmer collaborative sites to evaluate the effects of crop rotation and herbicide management on the population dynamics of brome (seedbank decline, build-up rates and persistence). More specifically, different levels of management structured around providing one, two and three years of effective management were deployed at the sites. Two key sites located on farms at Lock and Darke Peak on EP were identified for undertaking the work. The soil at these sites was considered non-wetting in nature and conducive to the persistence of the brome seedbank. Each population of brome was identified as *B. rigidus*, following examination of sampled seed. Initial (March-April) and residual (September) components of the seedbank of each population were routinely monitored from soil samples taken from plot areas under different crop and herbicide management.

Analysis of data on the residual seedbank showed that the carry-over of viable brome seed from one season to the next was higher than first anticipated and ranged from eight to 29% respectively. The level of carry-over was strongly influenced by seasonal effects. However, no clear association with the non-wetting characteristics of the soil was shown. This important finding provides some explanation as to why many growers were coming unstuck when planting cereals back onto well-managed pasture phases (grass selective and spray-topped) with the residual seedbank providing a persistent source for reinfestation. This finding reinforced the need for robust management strategies that provide three consecutive years of effective management.

Assessments of the longevity of brome seed were undertaken at each site. This was achieved by establishing zones excluding inputs of fresh seed and where the number of viable seeds remaining in the soil was quantified after two years. The results showed that after this period (two years) between two and 7% of the initial brome seed remained viable. Cheam (1988) similarly showed that un-germinated seeds of *B. diandrus* could remain viable in the field, especially on the soil surface, for two to three years. In order therefore to exhaust all viable seeds in the soil a period of three years of consecutive management is required. Although the exact mode of seed decline was not investigated here, it was evident that germination was mainly responsible for seed loss. It is also noteworthy that quantifying the proportion of seed lost to either predation or the processes of desiccation is difficult and requires further research.

The cultivation of different crop types and the herbicides used within these phases resulted in clear changes to the trajectory of the brome seedbank at the study sites (Attachment 1). Applications of Midas®# herbicide in Clearfield™ wheat resulted in an 80% decline in the brome seedbank, providing superior control and prevention of seed set. Similar reductions in the brome seedbank (80 to 90%) were reported following the use of grass selective herbicides Verdict®# and Targa®# in legumes (lupins and vetch) and the pasture phase. In contrast, a tank-mix of trifluralin# and Logran®# used in the wheat phase provided no effective control of brome, resulting in a two to three-fold increase in the seedbank. Regular use of these cheap herbicide mixtures by farmers has provided ineffective brome control in wheat and more than likely contributed to the proliferation of this weed in the low-rainfall regions of southern Australia.

Rotations that provided consecutive years of management included the combination of either a legume or pasture phase with Clearfield wheat. A third year of management was achieved by applying metribuzin#, which has good activity on brome, to either barley or metribuzin-tolerant wheat (i.e. cultivars Blade$^{\phi}$ or EGA Eagle Rock$^{\phi}$). This provided a three-year herbicide sequence of a grass selective such as Verdict or Targa (legume or pasture), followed by Midas (Clearfield wheat) then metribuzin (barley or tolerant wheat). These rotations were also considered to be sustainable from a herbicide resistance perspective as three different modes of action (A, B and C) were used. This combination effectively dropped the brome seedbank at Lock from 1,649 seeds/m^2 in 2003 to <26 seeds/m^2 at the end of 2005 (98% decline). In contrast, poor rotations comprising wheat on wheat followed by barley, with herbicides Atlantis®# and Treflan®# + Logran®# mixtures applied in the wheat phases, caused the initial seedbank (1,649 seeds/m^2) to rise between three and five-fold (4,853 to 8,805 seeds/m^2) over the same three-year period.

<u>Seedbank assessments of grower sites</u>

In addition to the key rotational sites, 15 grower paddocks on EP were monitored from 2004 to 2006 to quantify the change in brome seedbank with farmer management. Data collected from these sites enabled comparative analysis to be performed between farmer management and strategic rotations employed at the rotational sites. Farmers using the consecutive-year strategy of legume or pasture with Clearfield wheat significantly reduced their brome seedbanks. On the other hand, growers that were more relaxed with management were unable to effectively reduce the seedbank. Many growers were unable to capitalise on the legume and/or pasture phase, placing sole reliance on spray-topping applications of Gramoxone®#, which can be extremely sensitive to timing.

<u>Herbicide efficacy trials</u>

Several herbicide efficacy trials were undertaken during the project in the Mallee (n=3), and on Yorke Peninsula (YP) (n=4) and EP (n=6) to evaluate herbicide options available for controlling brome in wheat and barley. In Clearfield wheat several imidazolinone herbicides including Midas, Clearsol®# and Intervix®# were trialed and provided reliable and high levels(> 82%) of brome control. Additional treatments of cinmethylin# (Cinch®#) + pendimethalin# (Stomp®#), Atlantis®, Monza®# and trifluralin were also evaluated. However, these treatments routinely failed to achieve appropriate levels of control (<50%).

In 2004 a single trial was undertaken to evaluate herbicides Dual Gold®# (S-metolachlor#), Diuron#, Avadex®# and trifluralin alone and as mixtures in no-till sown wheat. These treatments provided no significant (P=0.157) control of brome compared to the untreated control. The use of Midas herbicide in Clearfield wheat is currently the best option available for the control of brome in this phase. However, grower concerns about lack of varietal choice (CLF Stiletto$^{\phi}$ or CLF Janz$^{\phi}$), cost of herbicide (>$35/ha) and issues of herbicide persistence will limit adoption of this technology.

Further research is required to investigate the persistence of the imidazolinone (IMI) herbicides in low rainfall environments and opportunities for breeding IMI-tolerant crop types (i.e. barley) for safe plant-back have been raised.

Previous research in WA in the mid to late 1980s identified metribuzin as an effective herbicide for selectively controlling brome in tolerant wheat and barley. Metribuzin alone at 180, 270 and 360 g/ha and in combination at 180 and 270 g/ha with trifluralin (1.2 L/ha) or pendimethalin (2.2 L/ha) were applied and incorporated by sowing (IBS) to barley grown at contrasting sites of heavy (YP) and light (EP) soil type. Mixtures of metribuzin with either trifluralin or pendimethalin provided safe yet effective levels of brome control (>78%) across sites and seasons. Although metribuzin at the highest rate (360 g/ha) provided superior weed control it was more phytotoxic to barley, reducing its plant density by 23% relative to the untreated control at Rudall site (EP) in 2004. Therefore, caution is required when using this mobile herbicide at higher rates, particularly on sandy-textured soils. A paper concerning this work titled 'Applications of metribuzin for the control of rigid brome (*B. rigidus*) in no-till barley crops of southern Australia' has been published in American journal 'Weed Technology' (Attachment 2).

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<u>Seed biology studies</u>

Several studies were undertaken at Roseworthy to investigate the germination behaviour of different populations of brome grass (*B. diandrus* and *B. rigidus*) collected from sites on YP and EP. Clear differences were shown between species, with populations of *B. diandrus* germinating at a much faster rate than its close relative, *B. rigidus*. Germination of *B. rigidus* seed was strongly inhibited by light and was under strong hormonal control. This effect was particularly profound for populations of *B. rigidus* collected from YP, which showed germination only with addition of gibberellic acid[#], a known stimulant, or by vernalisation treatment (cold stratification). This reluctance of *B. rigidus* to germinate would be of ecological benefit, allowing it to evade early control measures and germinate when the probability of seedling survival would be the greatest (May-July). A paper on this work titled 'Differences in the distribution and seed germination behaviour of populations of *Bromus rigidus* and *Bromus diandrus* in South Australia: adaptations to habitat and implications for weed management' has been published (2006) in the Australian Journal of Agricultural Research (Attachment 3).

Additional studies were undertaken to investigate the effect of climatic conditioning (drought stress) of seed and the implications of this for dormancy loss and germination in populations of *B. rigidus*. However, this study found no clear evidence to show that water stress imposed at seed maturation affects the dormancy status of seeds produced. Field work undertaken at Roseworthy showed that after-ripening conditions in summer-autumn were more likely to have a greater impact on the rate of dormancy release of seeds of brome.

<u>Screening wheat genotypes for metribuzin tolerance</u>

Previous field work undertaken in WA in the late 1980s identified the wheat cultivar Blade from the Roseworthy breeding program as having superior tolerance to metribuzin. Consequently glasshouse and growth-cabinet experiments were undertaken at Roseworthy to methodically screen Blade and its parents, sister and daughter lines to identify the origins of tolerance. Data showed that tolerance appears to be derived from the cultivar Kite[Φ], a direct parent of Blade. Although Kite appears to be a useful source of tolerance to metribuzin, wheat breeders are reluctant to use it due to the presence of SR26, a rust resistance gene that has been shown to be linked to yield penalty. There is a need therefore to identify alternative sources of metribuzin tolerance that can be incorporated into Australian wheats. As a consequence, work has begun with the screening of 44 lines of synthetic wheat sourced from the Horsham program.

With the collaboration of senior wheat breeder Haydn Kuchel of Australian Grain Technologies Pty Ltd (AGT), additional screening will also be performed on 600 back-crossed lines developed from crossing the metribuzin-tolerant cultivar EGA Eagle Rock and AGT Scythe[Φ]. A paper titled 'Differential tolerance in wheat (*Triticum aestivum*) genotypes to metribuzin' from this work has been published in the Australian Journal of Agricultural Research (Attachment 4).

Other research

The project has identified an effective methodology for screening wheat genotypes for metribuzin[#] tolerance which will be used to screen lines developed by the AGT breeding program by back-crossed EGA Eagle Rock[Φ] with Scythe[Φ]. This procedure can accurately screen hundreds of lines in a single run and potentially identify lines possessing superior tolerance to metribuzin and more agronomically desirable traits than those of EGA Eagle Rock.

At several grower meetings strong interest was shown in EGA Eagle Rock because of its tolerance to metribuzin and the potential for controlling brome in the wheat phase. However, growers are reluctant to grow this cultivar due to concerns about rust development and lower yields which have been reported for this variety. Varieties bred for tolerance to metribuzin could be widely grown by growers as a cost-effective alternative to Clearfield™ wheat. Strong collaborative links have developed between our research team and AGT senior wheat breeder Haydn Kuchel. With additional funding this collaboration has the potential to use this methodology to develop metribuzin-tolerant high-yielding cultivars.

Additional information

Additional information is provided as attachments to this project:

- **Attach1 –** Managing brome grass: importance of crop rotations and herbicide choice
- **Attach2 –** Applications of metribuzin for the control of rigid brome *(B. rigidus)* in no-till barley crops of southern Australia
- **Attach3** - Differences in the distribution and seed germination behaviour of populations of *Bromus rigidus* and *Bromus diandrus* in South Australia: adaptations to habitat and implications for weed management

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- **Attach4** – Differential tolerance in wheat *(Triticum aestivum)* genotypes to metribuzin