BOXER® GOLD, a flexible new pre-emergent herbicide alternative for the control of annual ryegrass (*Lolium rigidum* Gaudin) and toad rush (*Juncus bufonius* L.) in wheat and barley

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Summary Recent surveys of herbicide resistance in *Lolium rigidum* Gaudin (annual ryegrass) have highlighted increasing levels of resistance to the Group D mode of action (MOA) herbicide, trifluralin across southern Australia.

Boxer Gold (tested as A14429B) is a new alternative MOA pre-emergent herbicide from Syngenta Crop Protection for the control of annual ryegrass and toad rush (*Juncus bufonius* L.) in wheat and barley. The product contains 800 g L^{-1} prosulfocarb (Group J) and 120 g L^{-1} S-metolachlor (Group K). Extensive field and pot studies across Australia have shown Boxer Gold to provide equivalent or superior control of annual ryegrass to trifluralin when applied pre-emergent and incorporated by the sowing operation. A resistance screen of 22 trifluralin resistant annual ryegrass biotypes showed no cross resistance between trifluralin and Boxer Gold, thus providing growers with a different herbicide MOA for the pre-emergent control of annual ryegrass in wheat and barley.

Boxer Gold provides greater flexibility over current pre-emergent herbicide alternatives in relation to incorporation timing, allowing the product to be applied up to seven days prior to the sowing operation. The product may be used in both no-till knife point and conventional full disturbance seeding systems.

Keywords Boxer Gold, prosulfocarb, S-metolachlor, annual ryegrass, toad rush, Group D, resistance, wheat, barley.

INTRODUCTION

Trifluralin is now one of the most important herbicide options for the control of annual ryegrass and certain broadleaf weeds in no-till cropping systems. Resistance to trifluralin in annual ryegrass was first reported in the mid 1980s (Heap and Knight 1986, Howat 1987). Recent surveys of herbicide resistance in annual ryegrass (Table 1) have highlighted increasing levels of resistance to the Group D MOA herbicides across southern Australia. A survey of the major cropping areas of South Australia showed 35 to 54% of annual ryegrass samples to have detectable levels of resistance to trifluralin and between 15 to 21% of samples had high level resistance to trifluralin (Boutsalis *et al.* 2006).

The increased frequency of resistance to ACCase and ALS inhibiting herbicides and increased reliance on herbicides under no-till systems is likely to increase the selection pressure on Group D herbicides. It is therefore important that alternative pre-emergent herbicide options are evaluated in cereals in order to delay the onset of trifluralin resistance.

In Australia during 2008, Syngenta Crop Protection released Boxer Gold (800 g L^{-1} prosulfocarb and 120 g L^{-1} S-metolachlor), a soil applied pre-emergent herbicide for the control of annual ryegrass and toad rush in wheat and barley.

Prosulfocarb, S-(phenylmethyl) dipropylcarbamothioate, is a thiocarbamate herbicide initially developed as a low volatile alternative to volatile thiocarbamate herbicides, including triallate. The co-formulation of prosulfocarb and S-metolachlor belongs to the Group J and Group K herbicide MOA groups and has dual mode of action. The herbicide has multiple sites of action, including the inhibition of very long chain fatty acids (VLCFA) synthesis and subsequent cell membrane formation.

A resistance screen of 22 known trifluralin resistant annual ryegrass biotypes showed no cross resistance between trifluralin and Boxer Gold (Ruchs and Boutsalis 2007). This finding has significant implications as it provides growers with a different herbicide MOA for the control of annual ryegrass in wheat and barley.

Table 1. Summary of Group D resistance in annual ryegrass across southern Australia, where R is resistant (25% or greater survival), DR is developing resistance (15–24% survival) and S is susceptible (0–14% survival).

State	Samples with response (%)			Samples tested
	R	DR	S	
SA	21	14	65	103
VIC	9	6	85	181
NSW	0	3	97	312
WA[A]	<1	24	75	453

Source: Adapted from Boutsalis *et al.* (2006) and Owen, Walsh and Powles (2005).

[A] WA samples classified as R if ≥20% population survived or DR if 1–19% population survived.

MATERIALS AND METHODS

Boxer Gold is an emulsifiable concentrate liquid containing 800 g L^{-1} prosulfocarb and 120 g L^{-1} S-metolachlor. Field development of Boxer Gold in Australia began in 2004. Over 50 small plot replicated field trials and 100 large scale commercial evaluation trials were conducted by Syngenta and independent researchers throughout the major cereal growing areas. Independent third party researchers have also conducted a series of crop tolerance trials evaluating response to herbicide application in a wide range of major cereal cultivars.

Boxer Gold was evaluated in both incorporated by sowing (IBS) and post-sowing pre-emergence (PSPE) use patterns and compared to commercial standards applied at registered use rates. Comparisons included TriflurX* (480 g L^{-1} trifluralin), Triflur Xcel* (500 g L^{-1} trifluralin), Stomp* (330 g L^{-1} pendimethalin), Dual Gold® (960 g L^{-1} S-metolachlor) and various tank-mixtures of trifluralin with Avadex* Xtra (500 g L^{-1} triallate), diuron and metribuzin. Application was made using either hand held pressurised spray boom, quad bike mounted boom or large scale commercial boomspray. Assessments were made of weed control, stand count and crop vigour, crop phytotoxicity and grain yield.

RESULTS AND DISCUSSION

Efficacy in the control of annual ryegrass Boxer Gold is registered at 2300 g a.i. ha^{-1} solo or 1380–2300 g a.i. ha^{-1} + trifluralin at 384–720 g a.i. ha^{-1} for control of *Lolium rigidum* and 1150–2300 g a.i. ha^{-1} for control of *Juncus bufonius* in both wheat and barley. Extensive internal and independent field trials conducted on Group D susceptible populations have demonstrated that at 2300 g a.i ha^{-1} product, Boxer Gold provides control of annual ryegrass equivalent to the industry standard trifluralin applied at 1440 g a.i. ha^{-1} (Figure 1).

The low volatility of Boxer Gold and negligible risk of photodegradation allow the product to be applied up to seven days prior to sowing with no significant loss of weed control. Trials evaluating the performance of Boxer Gold when IBS compared with PSPE have demonstrated greater consistency in performance where the product is mechanically incorporated by the sowing operation (Figure 2).

Although the risk of product loss due to photo-degradation or volatilisation is low, mechanical incorporation reduces the reliance on rainfall for incorporation of product into the weed seed zone.

Moderate to high level suppression of some additional annual monocot and dicot weed species has also been observed in both replicated field trials and a pot trial of 15 major Australian weeds. Further work is required to add additional species to the proposed registration, but preliminary results have demonstrated 70–80% control of barley grass (*Hordeum* spp.) at 2300 g a.i. ha^{-1}. Activity on *Arctotheca calendula* (L.) Levyns, *Fumitory* spp., *Erodium* spp. and *Vulpia bromoides* (L.) Gray has also been observed.

Australian field trials on Group D resistant annual ryegrass populations have supported pot screening results that showed effective control of trifluralin re-

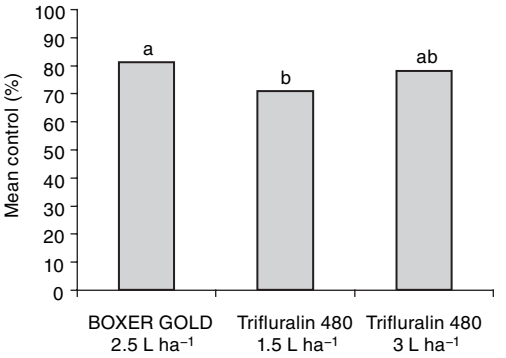

Figure 1. Mean *Lolium rigidum* control (%) for Boxer Gold relative to the industry standard trifluralin. Data is grand mean of 47 replicated field trials conducted across southern Australia from 2004–2007 and excludes Group D resistant sites. Treatments followed by the same letter are not significantly different ($P < 0.05$).

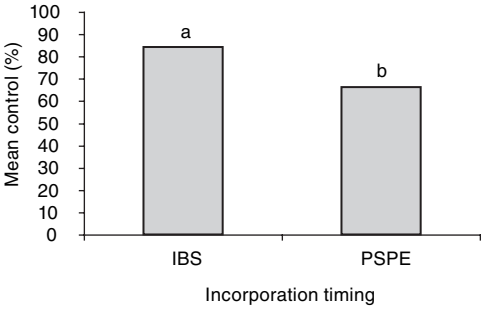

Figure 2. Comparison of mean *Lolium rigidum* control (%) for Boxer Gold when incorporated by the sowing operation (IBS) or applied post-sowing pre-emergence (PSPE). Data is grand mean of 47 replicated field trials conducted across southern Australia from 2004–2007 and excludes Group D resistant sites. Treatments followed by the same letter are not significantly different ($P < 0.05$).

sistant biotypes. Field trial results have demonstrated superior consistency of performance relative to common pre-emergent tank-mixtures across all sites due to Group D resistance development (Table 2).

Unlike trifluralin tank-mixtures that commonly incorporate sub-lethal dose rates of alternative MOA herbicides, the application of this herbicide at the maximum label use rate provides an effective rotational option to delay the onset of trifluralin resistance.

Table 2. Consistency of performance in the control of *Lolium rigidum* (% of sites with >75% control) for Boxer Gold vs. common herbicide mixtures.

Herbicide treatment	Sites with >75% ARG control (%)
BOXER GOLD 2.5 L ha^{-1}	80.4
Trifluralin 480 1.5 L ha^{-1}	56.8
Trifluralin 480 3 L ha^{-1}	62.5
Trifluralin 480 1.5 L ha^{-1} + DUAL GOLD 0.3 L ha^{-1}	55.2
TriflurX 1.5 L ha^{-1} + Avadex Xtra 1.6 L ha^{-1}	66.7
Trifluralin 480 1.5 L ha^{-1} + Diuron 500 0.5 L ha^{-1}	37.5

Summary of 52 replicated field trials conducted across southern Australia from 2004–2007.

Crop safety in wheat and barley Whilst the selectivity of Boxer Gold is a result of both physiological and positional selectivity, it is positional selectivity that is of primary importance. Thus in order for crop safety to be maintained it is important that accurate seed placement ensures that the herbicide is physically separated from the emerging crop. A minimum seeding depth of 15 mm is recommended. As Boxer Gold is mobile in the soil, especially the S-metolachlor component, risk of crop injury may be greater on sandy soils that are prone to leaching. In no-till knife point seeding systems the product should be concentrated in the crop-inter-row, whilst in full disturbance seeding systems it is important that seed is planted below the herbicide layer.

Extensive field testing of crop safety in both wheat and barley, including numerous herbicide tolerance tests at weed-free trial sites, have shown crop safety equivalent to trifluralin at 720–960 g a.i. ha^{-1}.

CONCLUSIONS

Boxer Gold provides a new option for the pre-emergent control of annual ryegrass and toad rush in wheat and barley. Being of alternative MOA, this herbicide may be used for the control of Group D resistant biotypes or as part of an integrated weed management program to delay the onset of trifluralin resistance.

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