Effect of wheat seed rate and herbicide on annual ryegrass control (Roseworthy)

Key messages

- A field trial was undertaken at Roseworthy in 2022 to investigate the effect of combinations of wheat seed rate and herbicide treatments on crop yield and annual ryegrass (ARG) control.
- The increase in wheat plant density in the range of 100 to 300 plants/m^2 improved suppression of ARG seed production (17-30%) and increased wheat grain yield (15-21%). However, herbicide treatments were the major driver of wheat grain yields and ARG suppression (P<0.001).
- The trial site had a large ARG seedbank that resulted in heavy and prolonged weed establishment. This was evident from inadequate ARG control achieved with pre-emergent herbicides alone. The trial site also had a detectable level of trifluralin resistance, which would have reduced efficacy of Trifluralin + Avadex Xtra® treatment.
- The sequential application of pre-emergent herbicides followed by an early post-emergent herbicide reduced ryegrass seed set by 94% compared to the untreated control and increased wheat yield by 4.57 t/ha.
- There was an exponential relationship between nitrogen recovery by wheat and ARG seed set, which accounted for >89% of the variation. Wheat plant density and herbicides treatments had a significant influence on nitrogen recovery in grain where only 300 wheat plants/m^2 recovered nitrogen equivalent to fertiliser N applied. Only herbicide treatments achieving >60% ARG suppression achieved nitrogen recovery greater or equivalent to applied fertiliser N.

Introduction

As a result of widespread resistance in annual ryegrass (ARG) to post-emergent herbicides in Australia, growers are now relying heavily on pre-emergent herbicides. This reliance on pre-emergent herbicides combined with resistance to established pre-emergent herbicides like Boxer Gold® and high levels of resistance to trifluralin has facilitated adoption of new pre-emergent herbicides Luximax® (Cinmethylin), Overwatch® (Bixlozone) and Mateno Complete® (Aclonifen + Diflufenican + Pyroxasulfone). The efficacy of pre-emergent herbicides can be negatively influenced by delayed emergence of ARG populations due to selection for increased seed dormancy. There is an increasing trend in the grains industry to follow up pre-emergent treatment with another herbicide treatment at 1-2 leaf stage of ARG (early post-emergent). This early post-emergent treatment has the desirable effect of extending the residual herbicide activity and often leads to improved weed control.
In an effective integrated weed management strategy as many control tactics should be utilised including non-chemical strategies. Increase in crop plant density has also been shown to improve weed suppression. In research by Lemerle et al. (2004), doubling wheat plant density from 100 to 200 plants/m^2 halved ryegrass shoot biomass. Therefore, higher wheat plant densities can be an effective component of weed management and should be integrated with herbicides.

This field trial at Roseworthy was undertaken to investigate factorial combinations of wheat seed rate, and herbicides packages on wheat grain yield and the management of annual ryegrass.

Methods

Table 1. Details of management practices used for crop and weed management.

Operation	**Details**
Location	Roseworthy, SA
Seedbank soil cores	Early June, 2022
Plot size	1.5 m x 10 m
Seeding date	18 June 2022
Fertiliser	At sowing: DAP (18:20) @ 120 kg/ha In season: 100 kg/ha urea (46:0:0) at mid tiller, 100 kg/ha urea Z30-31
Crop and variety	Scepter wheat
Seeding rate targets	1. SR 100, 100 wheat plants/m^2 2. SR 200, 200 wheat plants/m^2 3. SR 300, 300 wheat plant/m^2
Herbicide applications	1. IBS: herbicides applied to soil immediately before seeding pass (18 June). 2. EP: early post emergent, when wheat 1-2 leaf, and annual ryegrass 1 leaf stage (15 July).
Herbicides	All herbicides applied just before seeding 1. Untreated control 2. Trifluralin @ 2 L/ha + Avadex Xtra® @ 2 L/ha IBS 3. Sakura Flow® @ 210 mL/ha IBS 4. Overwatch® @ 1.25 L/ha IBS 5. Trifluralin @ 2 L/ha + Avadex Xtra® @ 2 L/ha IBS fb Boxer Gold® EP 6. Trifluralin @ 2 L/ha + Avadex Xtra® @ 2 L/ha IBS fb Mateno Complete® @ 1L/ha EP 7. Sakura Flow® @ 210 mL/ha IBS fb Boxer Gold® @ 2.5L/ha EP 8. Overwatch® @ 1.25 L/ha IBS fb Mateno Complete® @ 1L/ha EP

Trial design: factorial randomised block design

Replicates: 3

Measurements: pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, grain yield, grain protein, test weight and 1000-grain weight.

Rainfall received at Roseworthy during the growing season was 30% above the long-term average for the site. Total annual rainfall was 46% above the long-term average for the site. The year was characterised by a very dry autumn, only breaking with reasonable rains at the end of May, July had below average rainfall, while October and November had well above average rainfall. The November rainfall, though classed as outside of growing season rainfall (April-October), it was still of great use with the late maturing wheat crop of 2022 utilising the moisture (Table 2).

Table 2. Rainfall received at Roseworthy in 2021 and the long-term (1997-2023) average for the site.

	Rainfall (mm)	
Month	**2022**	**Long-term rainfall**
Jan	64.6	18.3
Feb	5.8	19.0
Mar	11.4	16.7
Apr	6.8	29.9
May	78.8	39.5
Jun	52.8	45.5
Jul	26.0	43.7
Aug	49.2	45.9
Sep	56.8	45.5
Oct	99.8	34.7
Nov	107.0	29.6
Dec	14.0	23.8
Annual total	573.0	392.3
GSR total	370.2	284.7

Results and Discussion

Crop plant density

As expected, increase in wheat seed rate resulted in a significant increase in wheat plant density (P<0.001). Wheat plant density achieved ranged from 99 plants/m2 (low), 168 wheat plants/m^2 in the medium seed rate and 249 wheat plants/m^2 in the high seed rate treatments. There was no significant effect from the herbicide treatments on wheat plant density relative to the untreated control. This suggests herbicide treatments investigated had good crop safety.

Annual ryegrass plant density and seedbank

The seedbank of annual ryegrass (ARG) at the site in the autumn of 2022 was 13708 seeds/m^2. Such a high weed seedbank is expected to provide an extremely uniform weed infestation for research.

As expected, wheat seed rate had no impact on ARG plant density (P=0.86). However, ARG plant density was significantly affected by the herbicide treatment (P<0.001) (Table 3). Untreated control plots had a mean ARG plant density of 1142 ARG plants/m^2. Herbicide treatments varied in efficacy from 55% to 98% control compared to the untreated control. Trifluralin + Avadex Xtra® IBS (425 ARG plants/m^2) provided 63% control of ARG plants. Application of early post-emergent (EP) Boxer Gold® to plots sprayed with Trifluralin + Avadex Xtra® IBS improved ARG control by only 9% (non-significant). In contrast, when Mateno Complete® EP was applied after Trifluralin + Avadex Xtra® IBS, ARG control was increased by 21%. This was similar to the weed control improvement achieved when Mateno Complete® EP followed Overwatch® IBS and ARG control improved from 80% to 98%, respectively. When Boxer Gold® EP was added to Sakura® IBS ARG control improved from 55% to 72% (Table 3). These results are encouraging and clearly show that the use of EP herbicide options can improve herbicide activity against ARG.

Among pre-emergent herbicides used on their own, Overwatch® provided the highest level of ARG control (80%). Sakura® IBS (55%) was relatively ineffective and provided weed control similar to Trifluralin + Avadex Xtra® IBS (63%). As a cautionary note, it needs to be mentioned that the high seedbank present at this trial site (13,000 seeds/m^2) resulted in prolonged weed establishment and would have been an important factor in reducing herbicide efficacy.

Table 3. The effect of herbicide treatment on ARG plant density; means followed by a different letter indicate significant differences (P=0.05).

Herbicide	**ARG plant density (plants/m^2)**
Untreated	1142 ***d***
Trifluralin + Avadex Xtra® IBS	425 ***c***
Sakura® IBS	513 ***c***
Overwatch® IBS	223 ***b***
Trifluralin + Avadex Xtra® IBS fb Boxer Gold ® EP	315 ***bc***
Trifluralin + Avadex Xtra® IBS fb Mateno Complete® EP	178 ***ab***
Sakura® IBS fb Boxer Gold® EP	318 ***bc***
Overwatch® IBS fb Mateno Complete® EP	27 ***a***
P<0.001, LSD = 154.6, cv rep = 13.6%	

Annual ryegrass spike density

Both wheat seed rate (P=0.003) and herbicide treatment (P<0.001) had a significant influence on ARG spike density, which in turn would affect ARG seed set. While increasing wheat seed rate had no influence on ARG plant density, it caused a significant reduction ARG spike density (Figure 1). ARG spike density declined from 551spikes/m^2 at SR100 to 410 spikes/m^2 at SR300, a reduction of 26% (Figure 1). These results support previous work in this project, which showed that ARG control can be significantly improved by using high wheat seed rate in conjunction with pre-emergent herbicides.

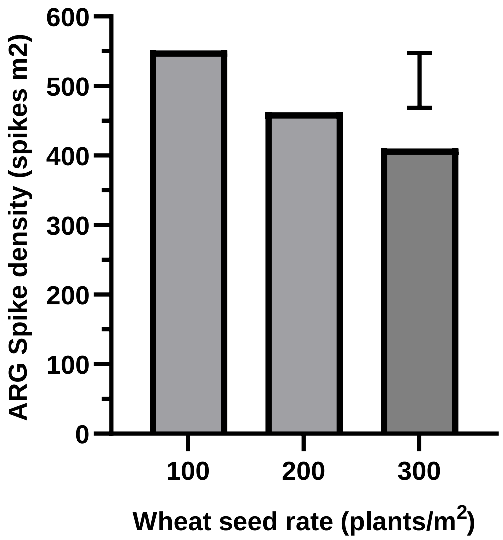

Figure 1. Influence of increasing wheat seed rate on ARG spike production, vertical line represents LSD (79.3 ARG spikes/m^2), cv rep = 3.6%, P=0.003.

Different herbicide treatments provided between 24% and 95% suppression of ARG spike density as compared to the untreated control (Figure 2). While the Trifluralin + Avadex Xtra® IBS treatment reduced ARG plant density by 63% (Table 3), it only suppressed ARG spike density by 24%. This disparity between plant density and spike density in Trifluralin + Avadex Xtra® IBS treatment indicates that survivors of this treatment were relatively unaffected. Presence of trifluralin resistance at this site, would have contributed to poor performance of this herbicide treatment. In contrast, Sakura® IBS treatment, which had similar ARG plant density as Trifluralin + Avadex Xtra®, had significantly lower ARG spike density. This result suggests that more persistent herbicides such as Sakura® continue to suppress surviving ARG later into the season and reduce its seed set potential. A similar trend can be seen in all treatments that included pyroxasulfone (Sakura® IBS or Mateno Complete®). The results from this trial support the importance of extending persistence of pre-emergent herbicides in soil through the use of sequential EP herbicide applications, especially in situations with large ARG seedbank and a long growing season.

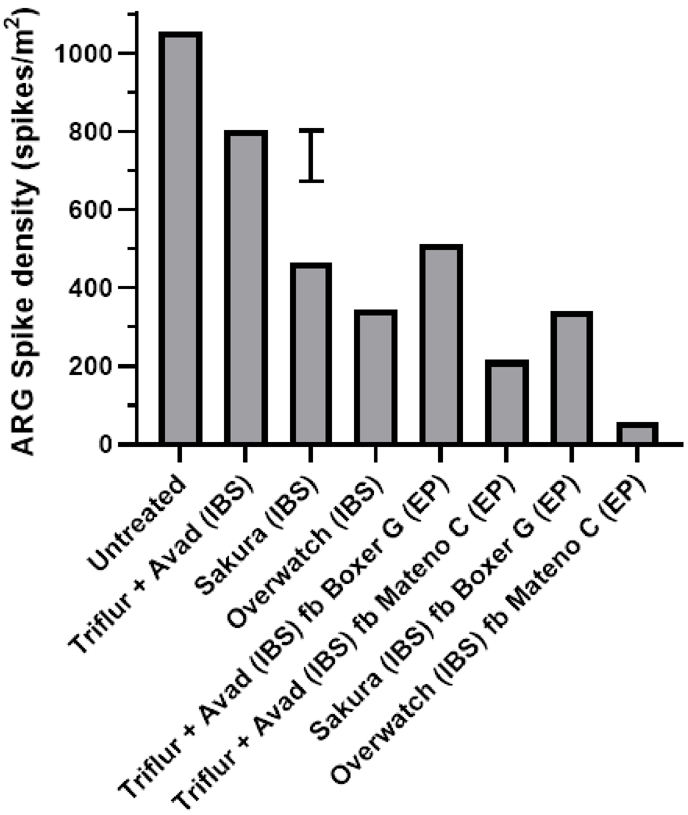

Figure 2. Influence of herbicide treatments on ARG spike production, vertical line represents LSD (129.5 spikes/m^2), cv rep = 3.6%, P<0.001.

Annual ryegrass seed production

Both wheat seed rate (P<0.001) and herbicide treatment (P<0.001) had a significant influence on ARG seed production, which is the source of future ARG infestations. When wheat seed rate was increased from SR100 to either SR200 (17%) and SR300 (30%) ARG seed production was significantly suppressed (Figure 3). This result supports previous research by the authors that increasing wheat seed rate is an effective non-chemical management tool to enhance crop competition and suppress ARG. It is a relatively inexpensive non-chemical control option that can be easily adopted and used in conjunction with variable rate technology.

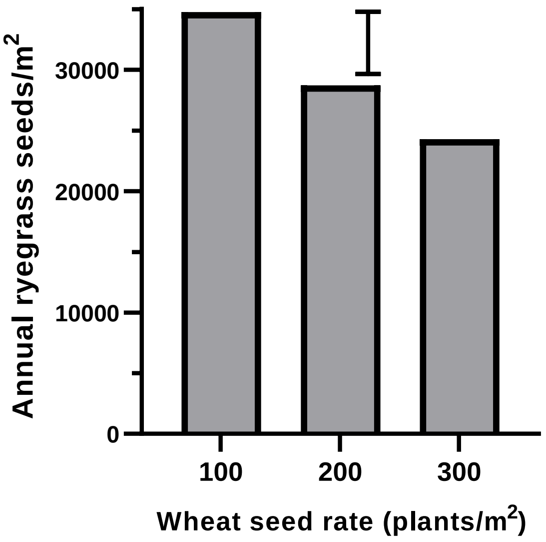

Figure 3. Influence of increasing wheat seed rate on ARG seed production, vertical line represents LSD (5128 seeds/m^2), cv rep = 4.8%, P<0.001.

Herbicide treatments provided between 10% and 94% suppression of ARG seed production compared to the untreated control (59272 ARG seeds/m^2) (Figure 4). Trifluralin + Avadex IBS despite controlling 63% of ARG plant density, suppressed ARG seed set by only 10% compared to the untreated control. Overwatch® IBS fb Mateno Complete® EP provided the highest suppression of ARG seed production at 98% compared to the untreated control. The next highest was Trifluralin + Avadex Xtra® IBS followed by Mateno Complete® EP at 77% ARG seed suppression. The use of EP herbicides seems to have an excellent potential to improve efficacy of pre-emergent herbicides in wheat. However, achieving these improvements in ARG control is highly dependent on soil moisture status and weed growth stage.

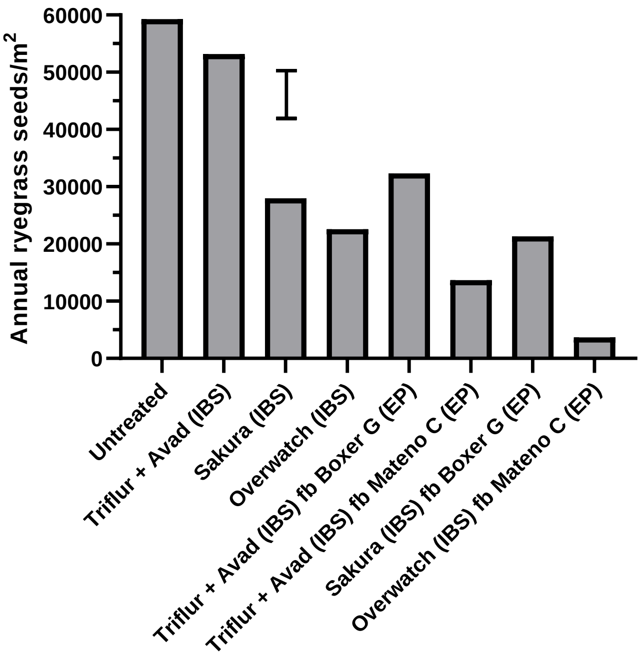

Figure 4. Herbicide treatment effect on ARG seed production, vertical line represents LSD (8374 ARG seeds /m^2), cv rep = 4.8%, P<0.001.

Grain yield and quality

Wheat grain yield across all treatments at the site averaged 5.038 t/ha. Grain yield was significantly influenced by wheat seed rate (P<0.001) and herbicide treatment (P<0.001). In this trial, increased wheat seed rates significantly improved ARG suppression (Figures 1 and 2) and wheat grain yield (Table 4). Such results should be reassuring for growers considering this practice where high ARG populations are present.

Table 4. Influence of wheat seed rate on grain yield (t/ha); means followed by a different letter indicate significant differences (P=0.05).

Wheat seed rate (plants/m^2)	**100**	**200**	**300**
Wheat grain yield *(t/ha)*	4.507 ***c***	5.173 ***b***	5.435 ***a***
P<0.001, LSD = 0.2384 t/ha, cv rep = 4.4%			

Herbicide treatment also had a significant influence on both wheat grain yield (P<0.001) and grain protein (P<0.001). When averaged across seed rates, grain yields ranged 2.845 t/ha for the untreated control to 7.412 t/ha for Overwatch® IBS fb Mateno Complete® EP (Figure 5). There was a general trend for higher grain yields in treatments with effective ryegrass control.

Grain proteins were generally low across the site. Wheat seed rate did not affect grain protein (P=0.23). Herbicide treatments resulted in grain protein ranging from 7.88% in the untreated to 9.71% in the Overwatch® IBS fb Mateno Complete® EP. Grain yield followed improved ARG suppression as did grain protein. In this trial grain protein increased as grain yield increased, despite the effect of dilution of protein as yields increase. This suggests that nitrogen uptake by ryegrass in weedy plots not only reduced grain yield but also grain protein.

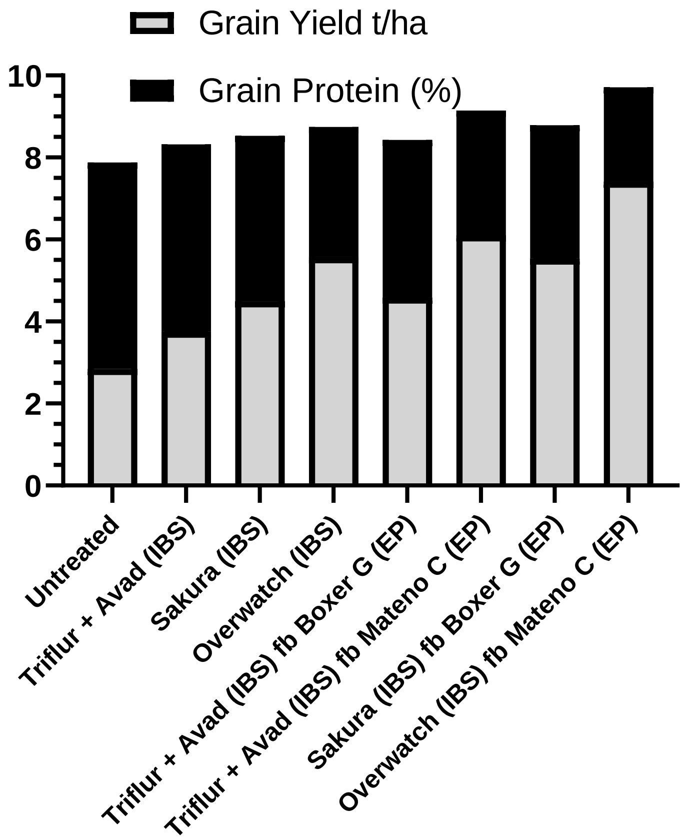

Figure 5. Influence of herbicide treatment on wheat grain yield (t/ha) and protein (%). Grain yield, LSD = 0.3893 t/ha, cv rep = 4.4%, P<0.001. Grain protein, LSD = 0.2203%, cv rep = 0.8%, P<0.001.

Grain test weight was high across the site with a mean of 81.26 kg/hL, and it was unaffected by wheat seed rate (P=0.49) and herbicide treatment (P=0.09).

The mean wheat grain size (1000 grain weight) for the site was 48.2 g/1000 grains and was significantly influenced by wheat seed rate (P<0.001) and herbicide treatment (P<0.001). There was an interaction between wheat seed rate and herbicide treatment (P=0.003). Data not shown, but seed rate did not change grain size in any herbicide treatment except for Overwatch® IBS fb Mateno Complete® EP, where 1000 grain size increased from SR100 (48.59 g/1000 grains) to SR200 (49.73 g/1000 grains) and SR300 (50.193 g/1000 grains).

There was a strong exponential relationship between ARG seed production (i.e., weed control) and grain yield, which accounted for >88% of variation in the data (Figure 6). These results highlight that ARG present at high densities can be highly competitive with wheat and yields respond positively to effective herbicide treatments. The curve is steepest at lower ARG pressures, highlighting the importance of managing ARG even when weed pressure is low.

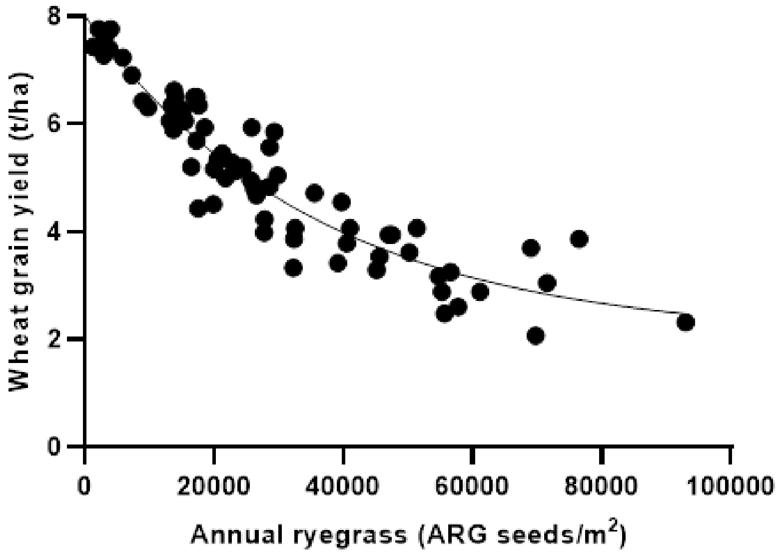

Figure 6. The relationship between ARG pressure (ARG seeds/m^2) and wheat grain yield (t/ha), R^2=0.88.

Nitrogen recovery

Nitrogen efficiency is topical in 2022 due to the substantial cost of nitrogen. The impact of ARG on nitrogen recovery was investigated. Grain nitrogen recovery kg N/ha was calculated by the following calculation:

Grain N recovery (kg N/ha) = Wheat grain yield (t/ha) x Grain protein (%) x 2.34

Wheat seed rate had a significant impact on Grain N recovery (GNR) (P<0.001). GNR increased with wheat seed rate (Figure 7), which is most likely related to yield improvement from increased ARG suppression. Averaged across herbicide treatments only SR300 achieved GNR equivalent to the rate of fertiliser N application.

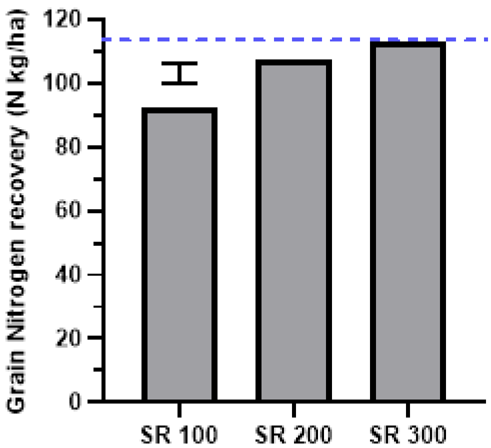

Figure 7. Influence of wheat seed rate on grain nitrogen recovery (kg N/ha), horizontal blue dashed line represents fertiliser applied nitrogen (113.6 kg N/ha), vertical line represents LSD (6.13 kg N/ha), cv rep = 5.2%, P<0.001.

Herbicide treatment had a significant influence on GNR (P<0.001) (Figure 8). GNR ranged from 52.4 kg N/ha in the untreated control to 168.5 kg N/ha for the Overwatch® IBS followed by Mateno Complete® EP. This is a remarkable result indicating that ARG was able to take up more 100 kg N/ha, thereby reducing yield potential of wheat. Only the Trifluralin + Avadex Xtra® IBS fb Mateno Complete® EP and the Overwatch® IBS fb Mateno Complete® EP had a GNR higher than the fertiliser nitrogen applied (113.6 kg N/ha). The Overwatch® IBS and Sakura® IBS fb Boxer Gold® EP treatments achieved GNR just above fertiliser N rate applied. Comparing these results with the ARG suppression (Figure 4), herbicide treatments needed to achieve >60% control of ARG to achieve a GNR equal or greater than fertiliser nitrogen applied.

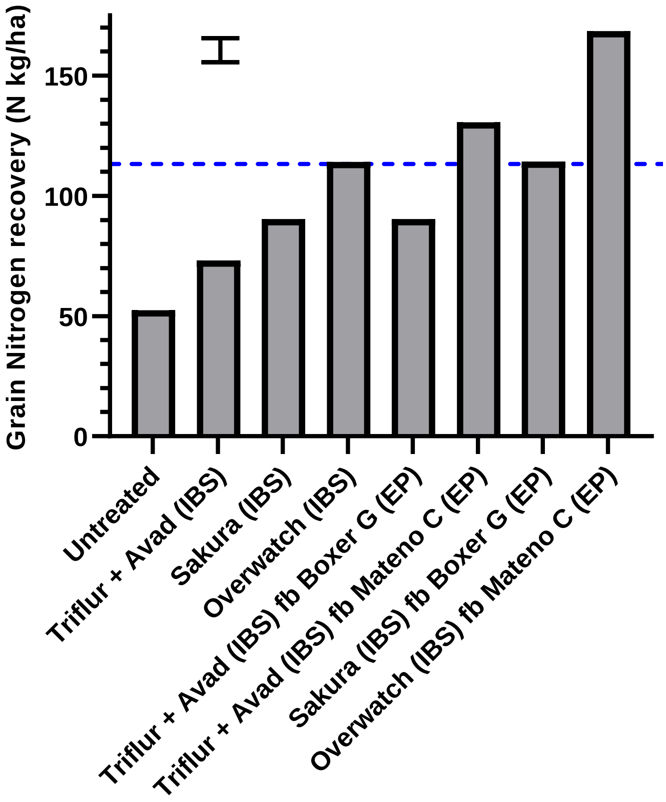

Figure 8. Effect of herbicide treatment on grain nitrogen recovery (kg N/ha), horizontal blue dashed line represents fertiliser applied nitrogen (113.6 kg N/ha), vertical line represents LSD (10.01 kg N/ha), cv rep = 5.2%, P<0.001.

A partial nitrogen balance (PNB) was also calculated for each plot (Figure 9). It was calculated using the following:

Partial nitrogen balance (PNB) = Grain nitrogen removal (kg N/ha) ÷ Nitrogen supplied (kg N/ha)

There was a strong exponential relationship between ARG seed production (i.e., weed control) and PNB in grain yield, which accounted for >89% of variation in the data (Figure 9). At a PNB of ≥1.00 the plot utilised ≥ nitrogen supplied by fertiliser. Where PNB <1.00, wheat was unable to acquire nitrogen due to competition from ARG. These results highlight that ARG present at high densities can be highly competitive with wheat for nitrogen and PNB responded positively to effective ARG control. The curve is steepest at lower ARG pressures, highlighting the importance of managing ARG even when weed pressure is low and crop nitrogen efficiency will be very low where ARG pressure is high as ARG is very competitive and its root system is highly effective at absorbing soil nitrogen.

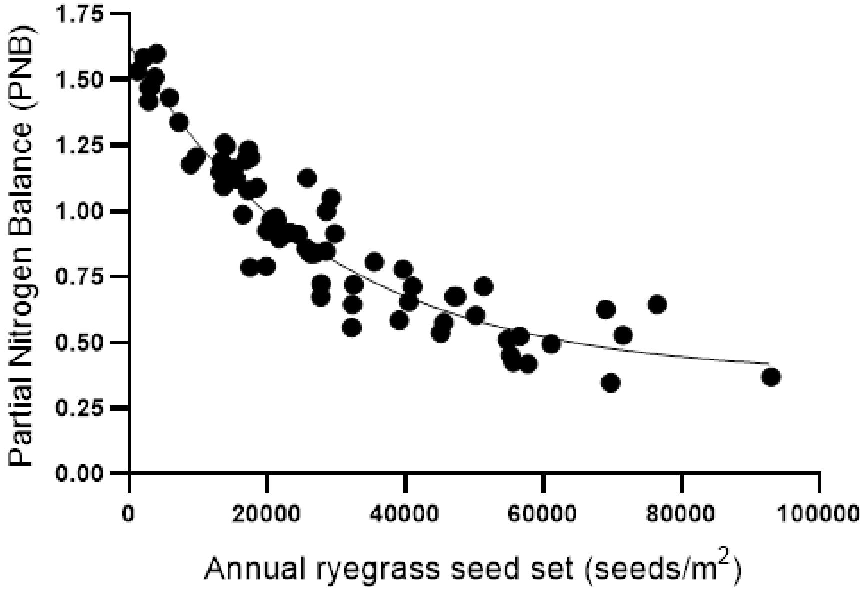

Figure 9. The relationship between ARG pressure (ARG seeds/m^2) and partial nitrogen balance, R^2=0.8988.