RUNNING TITLE:

Wheat time of seeding and pre-emergent herbicide effectiveness in wheat.

TITLE:

TRIAL GRDC 1: The interaction between wheat (*Triticum aestivum*) establishment timing and pre-emergent herbicides choice on annual ryegrass (*Lolium rigidum Gaud.*) growth and competition.

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Key Words; wheat, *Triticum aestivum* L., weeds, annual ryegrass, *Lolium rigidum* Gaudin, Pre-emergent herbicides, Time of seeding , crop competition, herbicide degradation.

KEY MESSAGE

- A combination of dry sowing and a pre-emergent herbicide choice yields greater than the standard sowing time.
- The seed production of ARG at the end of the season correlates with the pre-emergent herbicide soil persistence.
- Increasing crop seeding rates may affect ARG seed production at some sites.

INTRODUCTION

In the southern grainbelt of Australia, dry sowing has become popular as it enables growers to plant larger areas with limited machinery, within or before the optimum planting time to maximise yield potentials. At the same time, there has been an increased prevalence of grass weed populations with increased seed dormancy that emerge later to evade knockdown (glyphosate/paraquat) herbicide applications. To control these late emerging individuals there are several pre-emergent ‘residual' herbicides that can be safely used within no tillage farming systems to provide an extended period of herbicidal activity. These herbicides are often applied directly to the soil prior to planting.

In order to control these late germinating populations, it has long been advised that growers should delay seeding of weedy paddocks in order to maximise the weed control effectiveness of knockdown applications. However, any delay in seeding results in a sharp decline in the crops yield potential. Previously, dry seeding techniques have relied upon low weed seed banks as it places significant reliance on longevity and efficacy of soil applied herbicides that are often applied a long time before crop and weed germinating rains.

It has been however identified that with some pre-emergent residual herbicides, early seeding may now be the optimum weed control strategy as crops sown early into higher soil temperatures grow at a faster rate and have a competitive advantage against later emerging weed cohorts (Gomez-Macpherson and Richards, 1995). Crops that are seeded late generally grow slower and take longer for canopy closure, giving weeds a greater opportunity to establish and grow. Earlier sowing, when soil temperatures are generally warmer, provides an opportunity to increase the crops competitive advantage against weeds whilst maximising crop yield potentials. However, the early use of pre-emergent herbicides leads to increased rates of herbicide dissipation and microbial degradation. Past research by Minkey (2017) demonstrates that the decay of pre-emergent herbicides was more rapid in warm soil conditions with Sakura® (Pyroxasulfone) decaying at the slowest rate with Boxer gold® (Prosulfocarb + s-metolachlor) and Trifluralin having a faster rate of decay. The potential degradation of pre-emergent herbicides may offset the value of increased competitive crops as a result of earlier seeding.

This research aims to investigate the effect of wheat time of sowing and seeding rate, on the effectiveness and degradation of pre-emergent herbicides commonly used to control annual ryegrass in no tillage farming systems.

MATERIALS AND METHODS

Locations

In 2020, experiments were conducted in Tammin (-30.29S, 116.22E), Pingelly (-32.48S, 116.96E) and Dandaragan (-33.84S, 117.15E) in the Western Australian grainbelt. The soil characterization can be found in Table 1. The long-term (19 years) average growing season (April to October) rainfall at Tammin, Dandaragan, and Pingelly were 242 mm, 306 mm and 383mm; and soil pH (in $CaCl_2$) in the top 10cm of soil was 5.4, 6.5 and 4.6 respectively. Prior to this study, all sites had been under continuous no-till crop production for 10 years.

Table 1 Soil description at all 2020 experimental sites.

		Dandaragan	**Tammin**	**Pingelly**
	Depth (cm)	0-10	0-10	0-10
Colour		YWGR	LTGR	GRYW
Gravel	%	0	0	5-10
Texture		1.0	1.0	1.0
Ammonium Nitrogen	mg/kg	5	2	10
Nitrate Nitrogen	mg/kg	13	19	14
Phosphorus Colwell	mg/kg	25	35	40
Potassium Colwell	mg/kg	46	70	121
Sulfur	mg/kg	3.3	11.1	6.4
Organic Carbon	%	0.71	1.08	1.15
Conductivity	dS/m	0.047	0.107	0.050
pH Level (CaCl2)		6.5	5.4	4.6
pH Level (H2O)		7.2	6.2	5.7

Trial establishment

The first time of sowing (TOS1) took place in the first week of May and the second time of sowing (TOS2) in the first week of June. Each trial was direct seeded into cereal stubble. A factorial combination of wheat seeding rate, pre-emergent herbicide chemistry and time of seeding (TOS 1 plus TOS 2 (4-week delay)) was randomized in complete blocks with four replicates (Table 2). The wheat variety used was Magenta (Intergrain Australia) which is a high yielding, mid-late maturing variety, seeded at 25cm row spacing and 75kg ha^{-1}. The site was sown with no tillage tine openers with press wheels to provide sufficient seed soil packing and promote good weed germination. All plots were planted at one sowing depth (approx. 2cm) to minimise the confounding effects of emergence rate and seeding depth differences on biomass and grain yield. The Wheat seed was treated with a fungicide/insecticide seed treatment comprising of 300ml/ha of Uniform [322 g/L Azoxystrobin + 124 g/L Metalaxyl-M, Syngenta Australia] and 500mL/ha Aviator Xpro [75 g/L bixafen + 150 g/L prothioconazole, Syngenta Australia], applied to the fertiliser to protect against foliar fungal disease. Immediately prior to seeding, the whole experimental area was treated with 1.5L ha^{-1} Roundup Ultramax (Glyphosate 540 g/L, Sinochem Australia), 100ml ha^{-1} Lontrel (Clopyralid 750g/L, DowAgrosciences Australia), to control all germinated weeds; followed by the application of each individual plot's pre-emergent herbicide treatment (Table 2).

To control dicotyledonous species such as wild radish (*Raphanus raphanistrum* L.), all plots had a post emergent application of 670 ml/ha Velocity (210 g L Bromoxynil + 37.5 g L Pyrasulfotole, Bayer Australia). For the duration of this study, no additional annual ryegrass control was applied. All herbicides were applied using a motorized sprayer calibrated to deliver a carrier volume of 120 L water ha^{-1} at 275 kPa pressure. Each plot size was 2.2m wide by 10m long. To ensure optimal wheat growth, 100 kg/ha Gusto Gold (Summit Fertilisers Australia) (N – 10.2%, P- 13.1%, K- 12%, S- 7.6%, Cu- 0.07%, Zn- 0.14% and Mn- 0.01%) was drilled 3cm below the seed to minimise contact with the germinating wheat seed. To optimise crop growth supplementary nitrogen fertiliser in the form of urea (Summit fertilisers Australia) (N- 32%) was applied to all plots.

Table 2: Factorial combinations of wheat density, pre-emergent herbicide treatment and time of seeding of wheat at the Tammin, Pingelly and Dandaragan sites in 2020.

Treatments	Comments
Factor 1 - Crop density treatment description	
Low	100 plants/m^2
Optimum	150 plants/m^2
High	200 plants/m^2

Factor 2 - Time of sowing treatment description	
TOS 1	Dry seeded
TOS 2	Standard district practice time of seeding
Factor 3 - Pre-emergent herbicide treatment description (knockdown plus)	
Nil (knockdown only)	Nil herbicide applied control (knockdown glyphosate only)
Trifluralin 2.0 L/ha	Trifluralin 480 gai/L
Boxer Gold 2.5 L/ha	s-metolachlor 120 gai/L + Prosulfocarb 800 gai/L
Sakura 118 g/ha	Pyroxasulfone 850 gai/kg
*Overwatch ® 1.25 L/ha	Bixlozone (Isoxazolidinone) 400 g/L
*Luximax® 500mL/ha	750g/L Cinmethylin
*Mateno® 1 L/ha	Aclinofen + others TBA

*Added to the trial with no randomization at the optimum seeding rate only. Trials in 2021 will include randomization for improved statistical analysis.

At ten weeks after emergence (WAE), wheat establishment was assessed by counting two adjacent 50cm rows over 4 replicate locations per plot. Annual ryegrass density was assessed at 10 WAE by counting the number of plant present in four replicate a 33 x 33cm quadrants (0.11 m^{-2}) per plot.

Both incoming and outgoing photosynthetically active radiation (PAR) values were measured 14WAS at the top and bottom of the wheat canopy using line quantum sensor LI-191SA (LICOR Inc., Lincoln, NE, USA). The fraction intercepted (PAR) was calculated as per Monteith (1981)

$$PAR = \frac{(Io - I)}{I} \qquad [1]$$

where: Io is incident PAR at the top of canopy, and I is the transmitted PAR at the bottom of the canopy.

Above ground biomass samples of annual ryegrass were removed 27 WAE in three 0.25m^2 quadrants per plot. Biomass samples were dried at 60°C and weighed. From these samples, the number of ryegrass panicles were counted. In order to estimate annual ryegrass seed production, a representative sample of 50 panicles were collected from each plot and thrashed to extract seed. The number of seeds extracted was counted using an S-25 optical seed counter (Data Technologies, Kibbutz Tzora, Israel) to calculate the mean number of seeds produced per panicle. Total seed produced per plot was estimated by multiplying the average seed yield per panicle by the number of panicles produced.

At 28WAS, the whole plot (10 m length with 6 by 25-cm rows) was machine harvested to determine grain yield. Grain samples (400 g) were analysed for moisture and protein using an Infratec™ Sofia Near Infrared Spectroscope (NIR) (FOSS analytics, VIC, Australia).

Statistical Analysis

Experimental Design

As described above, the randomized complete block design (RCBD) accommodated two factorial experiment (crop density and pre-emergent herbicide) for different time of seeding. For each time of seeding, the treatment levels comprise factorial combinations of 12 levels. The 12 treatment combinations were replicated 4 times and were allocated in 6 ranges × 8 rows plot, where every two rows represent a replicate. Therefore, the overall treatment combinations are 24 levels, where 3 levels of crop density × 7 levels of herbicide × 2 levels of time of seeding.

Statistical Models

The data is fitted with general linear mixed model [3]. The model of a response variable, such as *Wheat Yield (t/ha)*, is in the following form

$$Yield_{ijk} \sim N(\mu_{ijk}, \sigma^2), \qquad [3]$$

where $\mu_{ijk} = TOS_i \times\ Density_j \times Treatment_k$ is the observation that crop density j ($j =$ 1,2,3) and pre-emergent herbicide treatment k ($k = 1, \dots ,4$) were applied with time of seeding i ($i = 1,2$). A two-dimensional separable autoregressive spatial structure AR1 x AR1 is assumed for the errors in the analysis, due to the plots of two times of seeding being conducted separately in this experiment. Hence, the replicates are nested within TOS and in the random term in the model. The model is fitted maximizing the restricted maximum likelihood (REML) using the R-package Asreml-R (Butler et al., 2009; Gilmour et al., 1995). The test for the fixed effect is performed using the Wald-test.

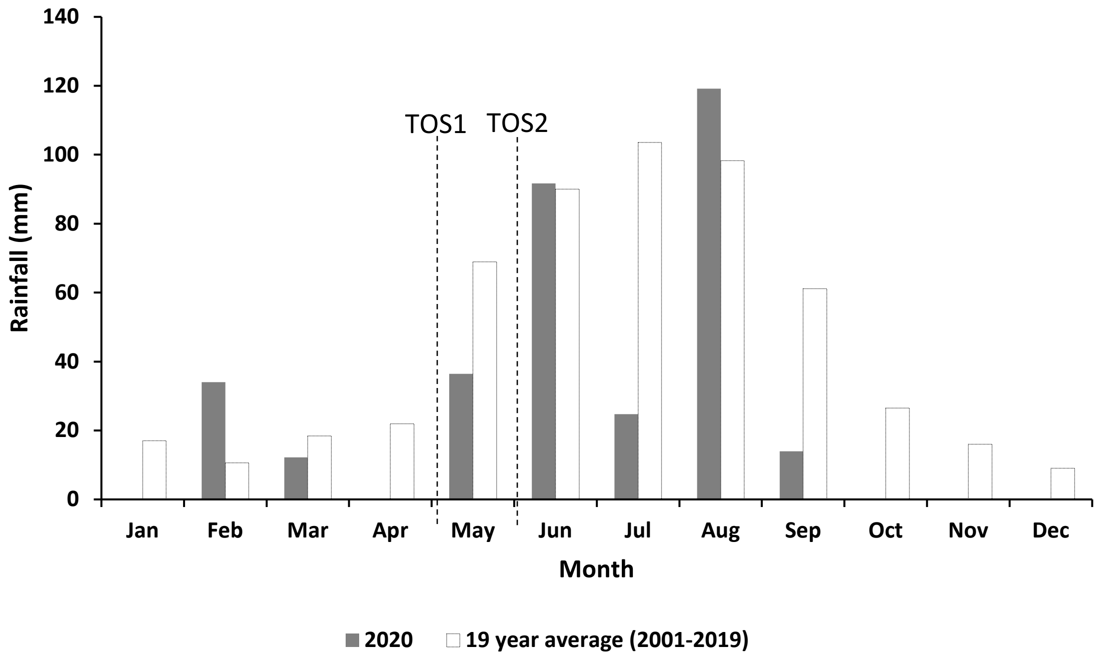
Results

Dandaragan 2020

At the Dandaragan site, the first time of seeding (TOS 1) was 7th May and the second time of seeding (TOS 2) was on the 5th June (Figure 2). The soil in the top 10cm was a yellow grey sandy loam with a pH 6.5 $Cacl_2$ and organic total carbon content of 0.71% (Table 1).

Figure 1 Dandaragan field site, TOS 2 (Left) sown on 5th June and TOS 1 (right) sown on 7th May.

The first TOS was seeded in dry soil moisture. The second TOS was seeded into good soil moisture after 36 mm of rain in May, providing an excellent and rapid germination. Following seeding, subsequent rainfall in June was average with a very dry July relative to the average 19 year rainfall, though August had higher than average rainfall providing acceptable soil moisture for the rest of the season (Figure 3).



A.

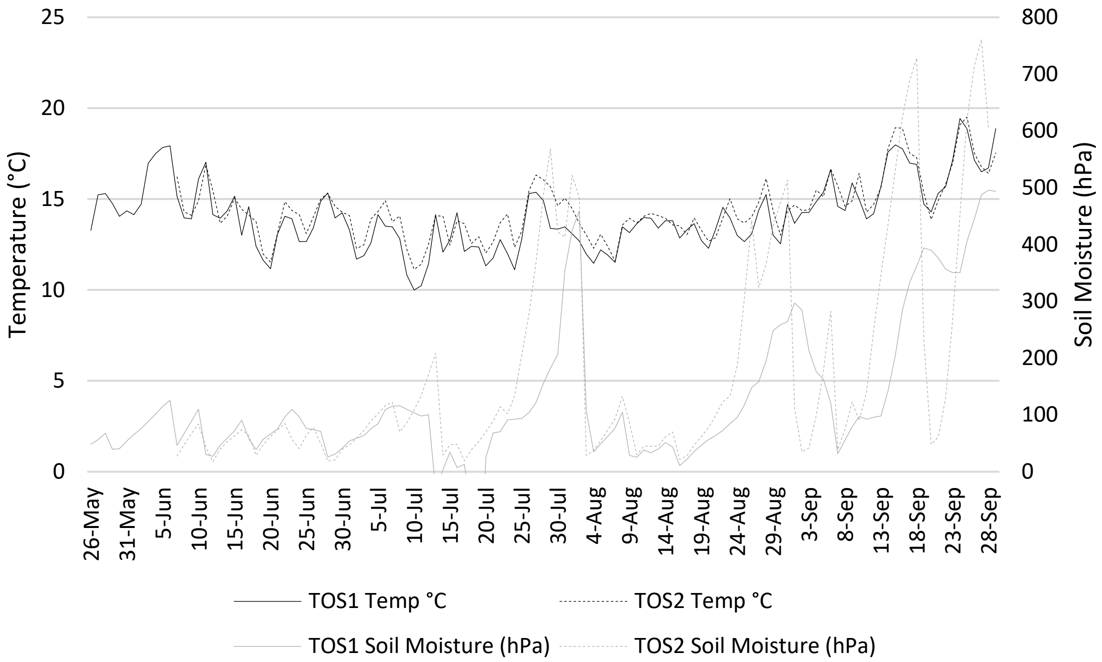


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Figure 2: A: Rainfall data at Dandaragan in 2020, B. Soil moisture and soil temperature data logged within each TOS where with soil moisture readings, greater pressures indicate drier soil conditions.

Effect of pre-emergent herbicide efficacy, Time of crop seeding and wheat seeding rate on ryegrass seed production

Annual ryegrass seed production

Time of crop seeding had a statistically significant effect on ryegrass biomass and seed production with the TOS 1 treatments found to have an increased ryegrass seed production compared to TOS 2 (P<0.001). Pre-emergent herbicide choice and seeding rate were also significant (P<0.001) (Figure 5) (Table 4).

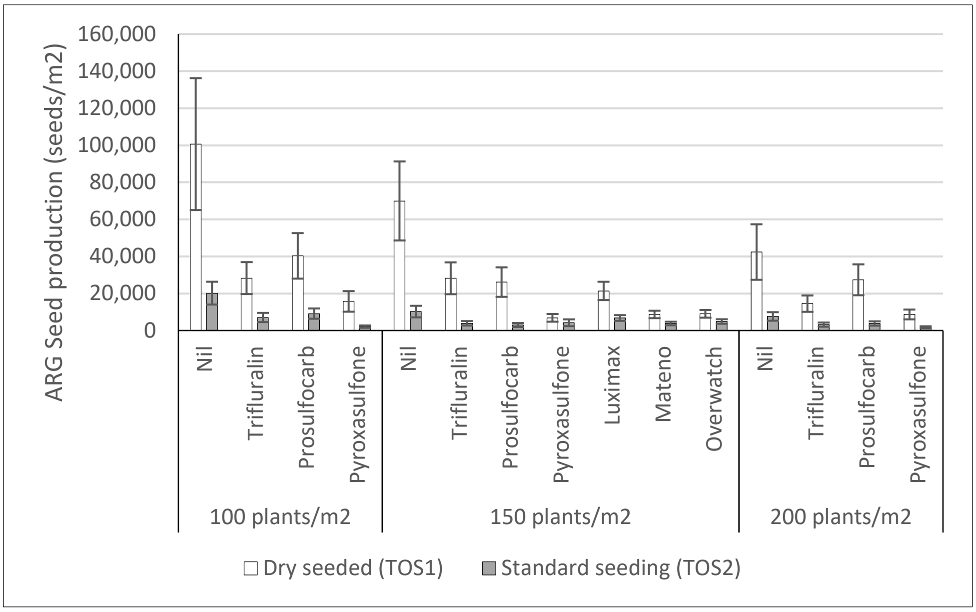

Figure 3: Annual ryegrass seed production at the Dandaragan site in 2020.

Wheat yield

At the Dandaragan site in 2020, a significant interaction between time of seeding and pre-emergent herbicide was found (p<0.001), and these two factors were also significant as main effects (p<0.001) (Table 3). These results suggest that not all the herbicides behave similarly under different times of seeding; however, yield gains were achieved at all seeding rates for TOS 1. On the other hand, for TOS 2, the pre-emergent herbicide treatments did not have a significant gain compared to their respective nil herbicide treatments, and this is likely due to the effect of the knock down herbicide application which would have controlled most ryegrass seedlings. Also, across all seeding rates and pre-emergent herbicides, TOS 2 produced the same or greater yields than TOS 1 except for mateno and overwatch at the optimum seeding rate and trifluralin at the higher seeding rate (Figure 7).

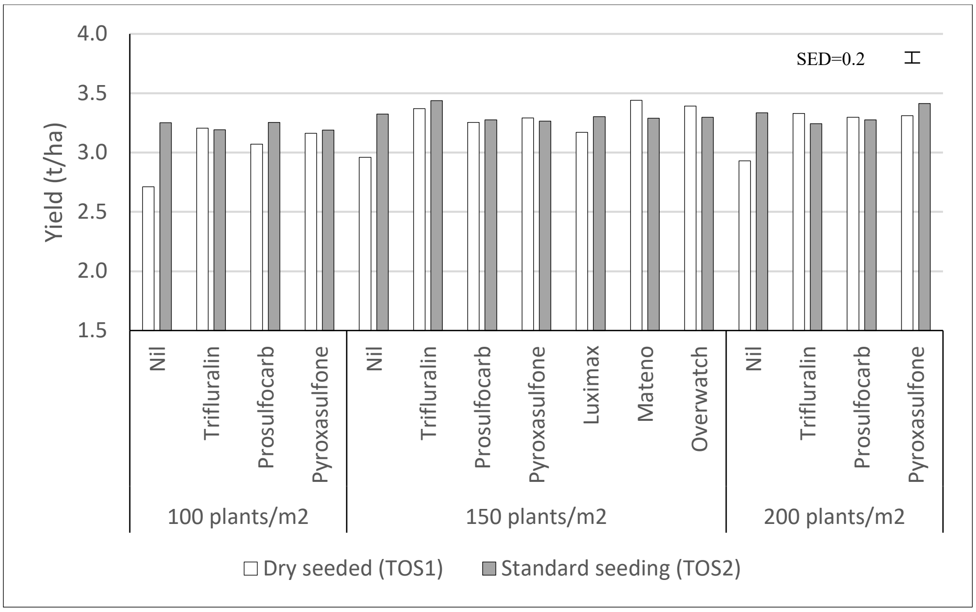

Figure 4: Wheat yield from TOS, wheat seeding rate, and pre-emergent herbicide treatments at Dandaragan in 2020

Tammin 2020

At the Tammin site, the first time of seeding (TOS 1) was 6th May and the second time of seeding (TOS 2) was on the 5th June. The soil in the top 10cm was a light grey sandy clay with a pH 5.4 Cacl2 and a total organic carbon of 1.08% (Table 1).

Generally low ryegrass densities were observed at this site compared to the other trials at Dandaragan and Pingelly. Even though May and June had higher than average rainfall the rest of the growing season was very dry with lower than average rainfall (Figure 8).

A.

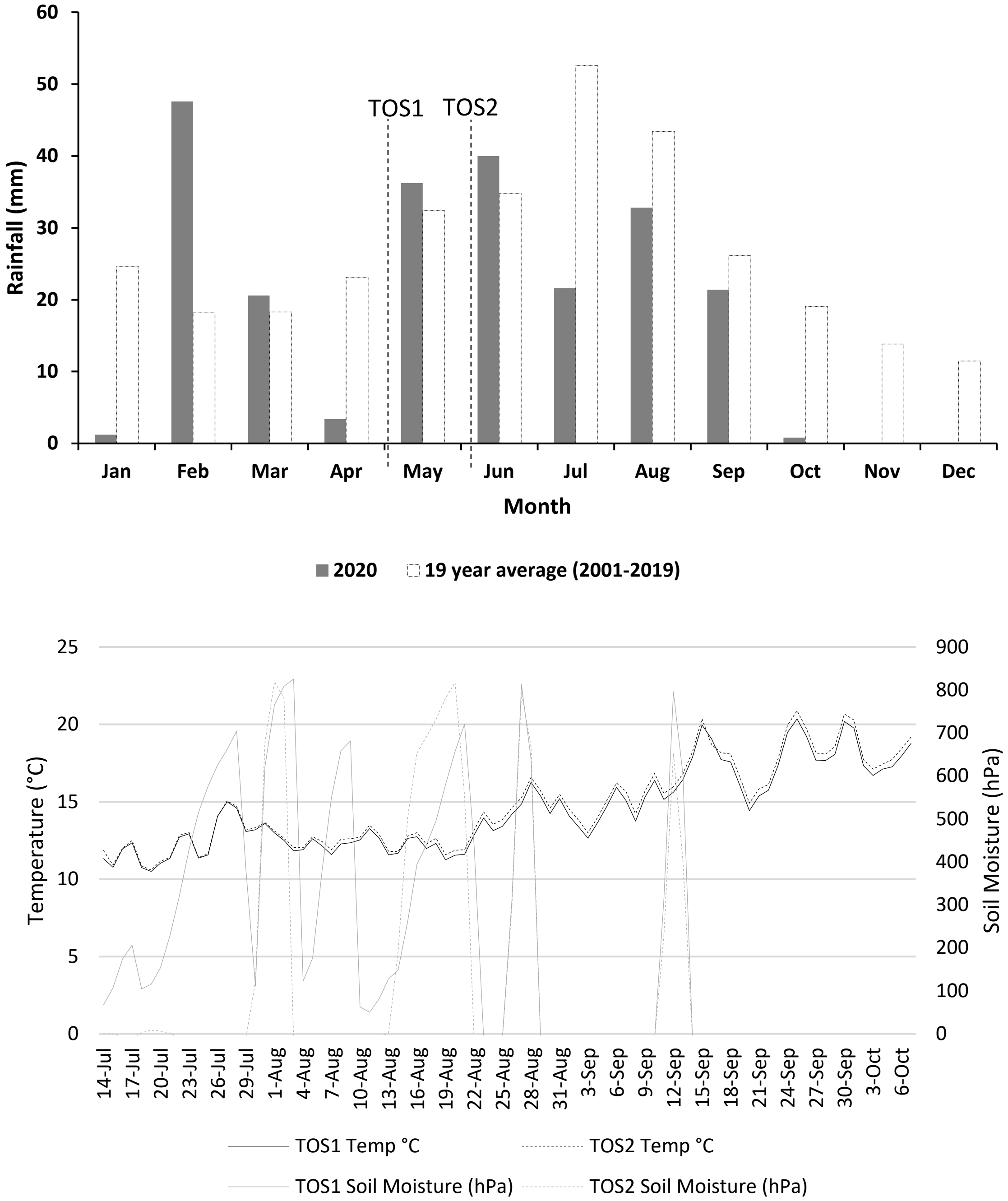

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Figure 5: A: Rainfall data at Tammin in 2020, B. Soil moisture and temperature data logged within each TOS.

Effect of pre-emergent herbicide efficacy, Time of crop seeding and wheat seeding rate on ryegrass seed production

Annual ryegrass seed production

At this site significant interactions between seeding time, seeding rate, and pre-emergent herbicides were found ($p<0.005$) (Table 6). TOS 2 had lower ARG seed production across all treatments than

TOS 1, and also seed production decreased with increasing wheat seeding rates. Pyroxasulfone, luximax, mateno and overwatch provided the best level of control with ARG densities of less than 9,000 seeds/m2 at both TOS (Figure 11).

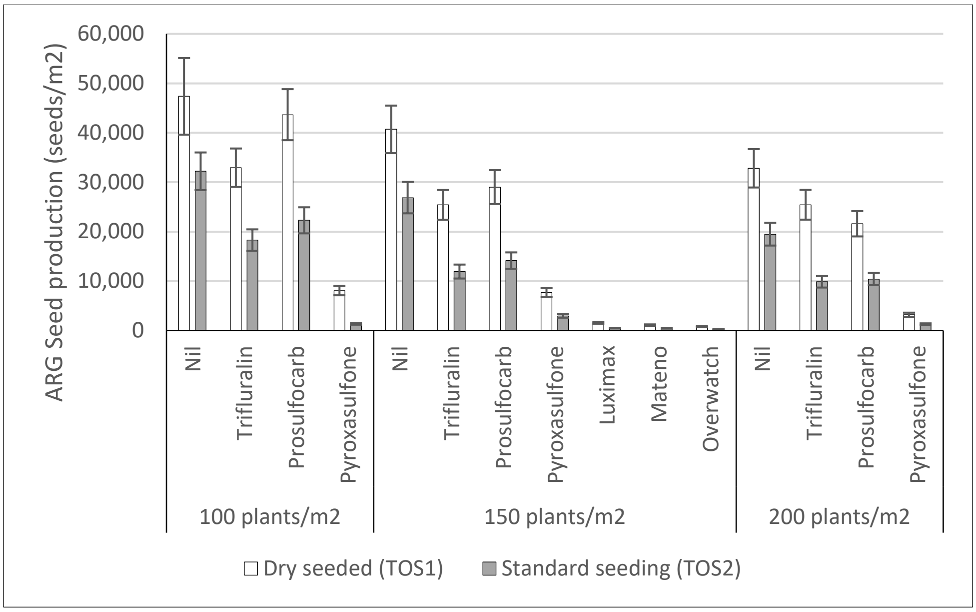


Figure 6: Annual ryegrass seed production at the Tammin site in 2020.

Wheat yield

No significant interactions were found for Tammin ($p>0.05$). However, pre-emergent herbicide and seeding rate were significant, $p=0.025$ and $p=0.009$, respectively (Table 5). Even though time of seeding was not significant, a trend can be observed where TOS 1 presented higher yields than TOS 2, except for Pyroxasulfone at the lowest seeding rate and Mateno at the optimum seeding rate (Figure 12).

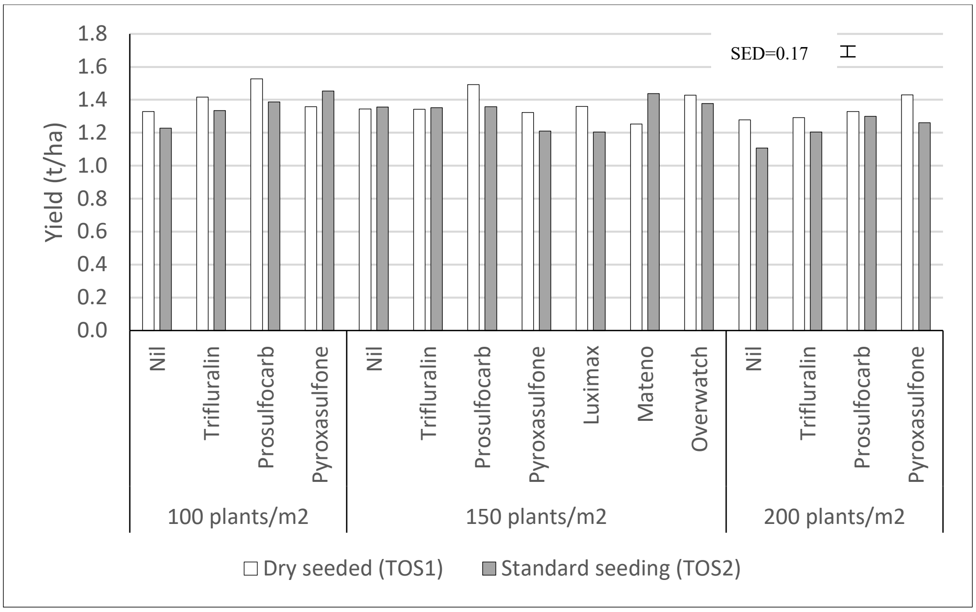
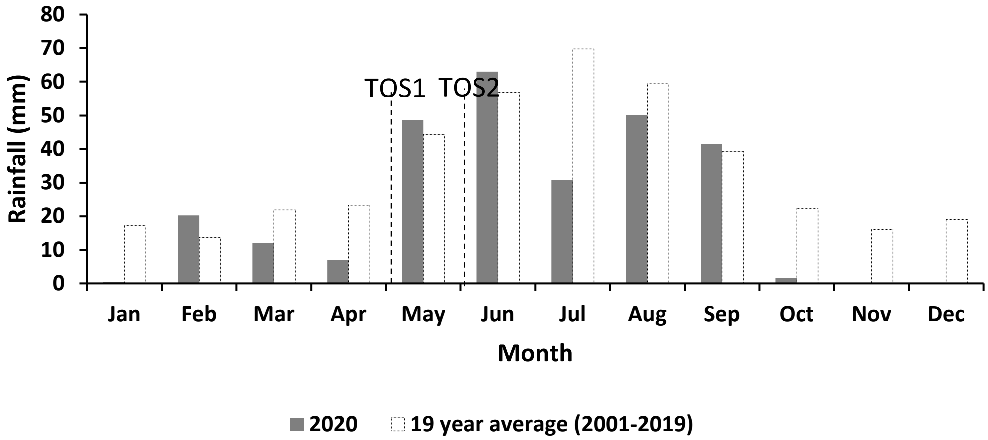


Figure 7: Wheat yield from TOS, wheat seeding rate and pre-emergent herbicide treatments at Tammin in 2020.

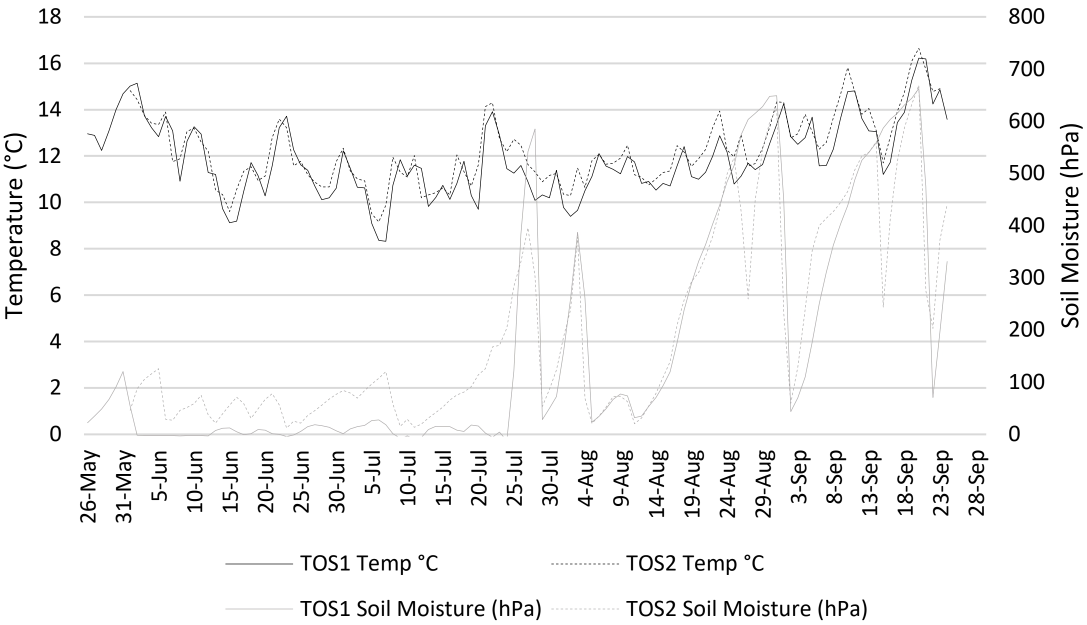
Pingelly 2020

At the Pingelly site, the first time of seeding (TOS 1) was 9th May and the second time of seeding (TOS 2) was on the 4th of June. The soil in the top 10cm was grey yellow sandy gravel with a pH 4.6 $CaCl_2$ and a total organic carbon content of 1.15% (Table 1).

TOS 1 was seeded dry in early May with limited rainfall of <10 mm in April, although soon after seeding 48 mm of rain fell in May providing good moisture for germination of crop and weeds followed by 63 mm of rainfall in June when TOS 2 was sown. The rest of the season provided lower than average rainfall (Figure 13).



A.



B.

Figure 8: A: Rainfall data at Pingelly in 2020, B. Soil moisture and temperature data logged within each TOS.

Effect of pre-emergent herbicide efficacy, Time of crop seeding and wheat seeding rate on ryegrass seed production

Ryegrass seed production

At this site, no significant interactions between time of seeding, pre-emergent herbicide, and seeding rate were found ($p>0.05$). However, the choice of pre-emergent herbicide and time of seeding were significant ($p<0.001$) (Table 8). For all pre-emergent herbicide choices, TOS 1 had significantly greater number of seeds compared to TOS 2, including the Nil herbicide control treatments (Figure 15). This highlights that even though all the pre-emergent herbicides had an effect in reducing the seed production of ARG in TOS 1 (dry seeded), the application of a knockdown herbicide four weeks later and before TOS 2 had an important effect in reducing ARG establishment across all treatments.

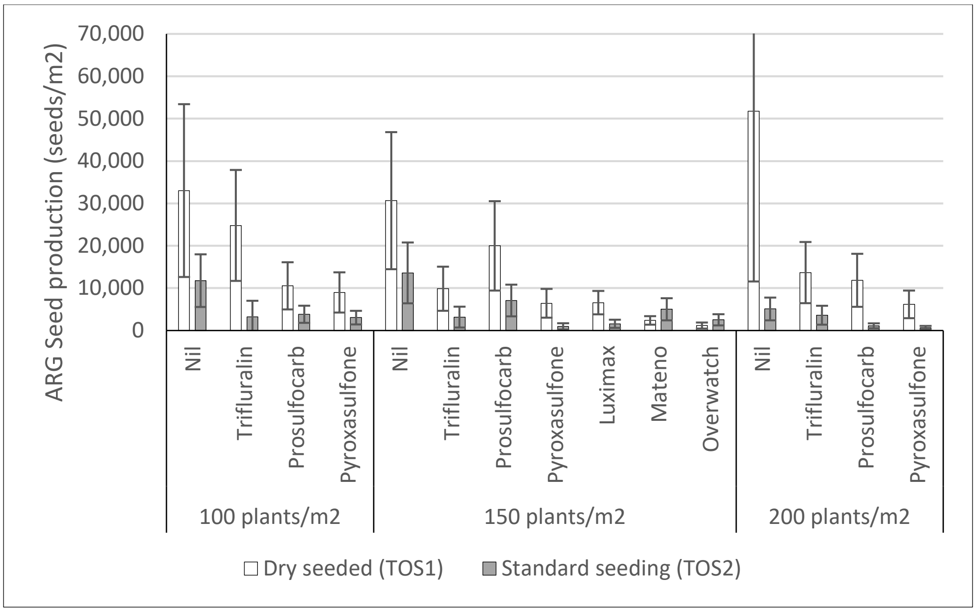


Figure 9: Annual ryegrass seed production at the Pingelly site in 2020.

Wheat yield

Significant interactions were found between seeding time and pre-emergent herbicide (p=0.019) and seeding time and seeding rate (p=0.017). Also, all the individual factors were significant (p<0.05) (Table 7). Across all treatments TOS 1 had greater yields than TOS 2, and yield generally increased with higher seeding rates at all treatments in TOS 1 (Figure 17). In TOS 2 however, yield did not change with increasing seeding rates, although at the optimum seeding rates, treatments where Luximax, Mateno, and overwatch were used out yielded the trifluralin, Prosulfocarb and Pyroxasulfone treatments.

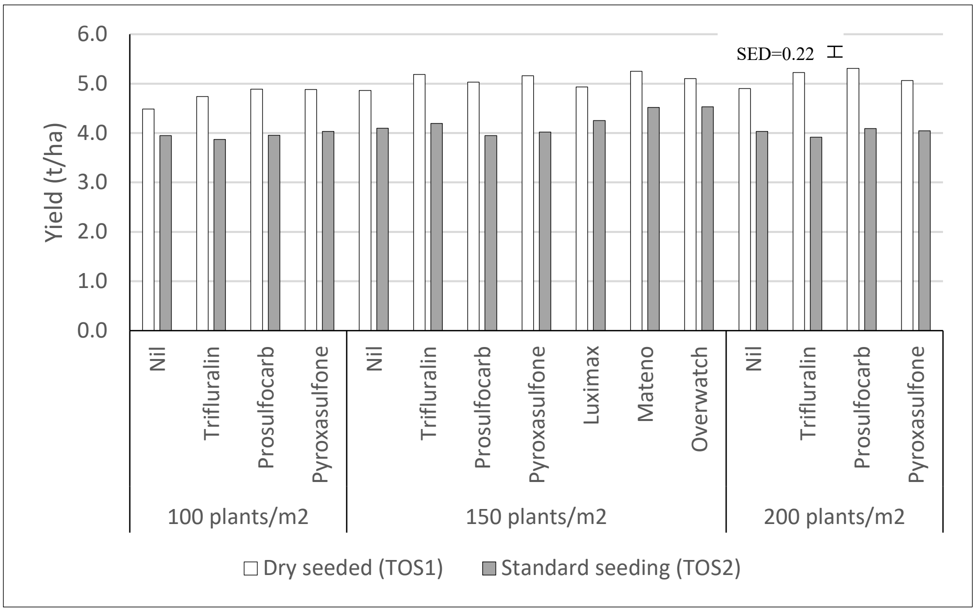


Figure 10: Wheat yield from TOS, wheat seeding rate and pre-emergent herbicide treatments at Pingelly in 2020

Conclusion

The general results across all sites suggest that TOS 1 out yielded TOS 2 except for Tammin which showed no timing response due to a dry season. However, the number of ARG seeds at the end of the season was significantly greater for TOS 1 than for TOS 2. Also, the bioassay assessments showed that the persistence of the pre-emergent herbicide on the soil throughout the season correlate with the quantity of ARG seeds at the end of the season. Generally, Prosulfocarb and Trifluralin degraded the fastest and therefore the quantity of ARG seeds at the end of the season is greater for these herbicides than for the other herbicides tested. However, it is possible to increase the length of effective residual control by applying a higher dose of these herbicides (Congrave and Cameron, 2018), though different doses have not been tested at this trials.

Appendix

Table 3 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Dandaragan - Part A.

Crop seeding time	**Crop seeding rate**	**Pre-emergent herbicide**	**Wheat Yield (t/ha)**		**Crop emergence (plants/m2)**		**Weed density (plants/m2)**		**Radiation interception (µmol m-2 s-1)**	
			Predicted value	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**
Dry seeded (early TOS1)	Low	Nil	2.710	0.126	109.500	5.638	35.333	16.408	800.005	49.958
		Prosulfocarb	3.071	0.126	97.250	5.638	12.500	5.116	775.325	49.958
		Pyroxasulfone	3.161	0.129	98.250	5.638	8.000	3.345	681.155	49.958
		Trifluralin	3.207	0.127	118.000	5.638	5.250	2.262	855.298	49.958
	Optimum	Nil	2.961	0.126	128.000	5.638	20.500	8.261	884.463	49.958
		Prosulfocarb	3.253	0.126	135.250	5.638	7.000	2.951	798.063	49.958
		Pyroxasulfone	3.293	0.126	116.500	5.638	4.000	1.768	859.005	49.958
		Trifluralin	3.369	0.127	123.000	5.638	11.000	4.526	860.023	49.958
	High	Nil	2.929	0.129	115.371	6.510	31.750	12.684	962.568	49.958
		Prosulfocarb	3.298	0.126	132.000	5.638	12.750	5.214	883.680	49.958
		Pyroxasulfone	3.310	0.127	137.750	5.638	4.000	1.768	799.553	49.958
		Trifluralin	3.331	0.127	136.000	5.638	3.000	1.373	851.600	49.958
Delayed seeding (frost optimum timing TOS2)	Low	Nil	3.250	0.112	116.500	5.638	15.500	6.295	448.145	49.958
		Prosulfocarb	3.255	0.111	116.250	5.638	3.750	1.670	438.465	49.958
		Pyroxasulfone	3.188	0.110	103.750	5.638	1.750	0.874	440.678	49.958
		Trifluralin	3.193	0.112	109.000	5.638	1.000	0.569	420.985	49.958
	Optimum	Nil	3.323	0.112	138.500	5.638	7.750	3.247	472.883	49.958
		Prosulfocarb	3.276	0.111	136.750	5.638	6.500	2.754	508.362	49.958
		Pyroxasulfone	3.265	0.111	135.750	5.638	0.000	0.000	509.735	49.958
		Trifluralin	3.438	0.111	132.250	5.638	1.750	0.874	519.385	49.958
	High	Nil	3.336	0.112	153.750	5.638	9.750	4.034	381.590	49.958
		Prosulfocarb	3.277	0.112	152.250	5.638	2.250	1.074	452.455	49.958
		Pyroxasulfone	3.414	0.113	144.750	5.638	0.500	0.357	517.540	49.958
		Trifluralin	3.243	0.113	152.750	5.638	0.000	0.000	532.895	49.958
Source of variation	***averaged SED***		***0.144***		***8.020***		***NA***		***70.651***	
Seeding time			NS		0.003		<0.001		<0.001	
Seeding rate			<0.001		<0.001		NS		0.011	
Pre-emergent herbicide			<0.001		NS		<0.001		NS	
Seeding time x Seeding rate			NS		0.039		NS		NS	
Seeding time x Pre-emergent herbicide			<0.001		NS		NS		NS	
Seeding rate x Pre-emergent herbicide			NS		NS		NS		NS	
Seeding time x Seeding rate x Pre-emergent herbicide			NS		NS		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

Table 4 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Dandaragan - Part B.

Crop seeding time	**Crop seeding rate**	**Pre-emergent herbicide**	**Radiation interception (%)**		**Seed Production ARG (Seeds/m2)**		**Biomass Wheat (g/m2)**		**Protein %**	
			Predicted value	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**
Dry seeded (early TOS1)	Low	Nil	83.554	3.780	100621.877	35609.778	1476.500	97.353	11.875	0.099
		Prosulfocarb	70.173	3.780	40287.600	12286.261	1574.700	97.353	12.275	0.099
		Pyroxasulfone	64.247	3.780	15706.666	5558.697	1504.200	97.353	12.275	0.099
		Trifluralin	85.975	3.780	28296.798	8629.547	1453.100	97.353	12.200	0.099
	Optimum	Nil	86.516	3.780	69948.399	21331.617	1392.000	97.353	11.975	0.099
		Prosulfocarb	75.140	3.780	26139.200	7971.566	1461.700	97.353	12.175	0.099
		Pyroxasulfone	80.704	3.780	6832.400	2083.766	1496.300	97.353	12.400	0.099
		Trifluralin	79.277	3.780	28197.601	8599.296	1501.300	97.353	12.275	0.099
	High	Nil	81.001	3.780	42358.399	14990.616	1253.800	97.353	12.050	0.099
		Prosulfocarb	81.964	3.780	27379.200	8349.717	1493.400	97.353	12.250	0.099
		Pyroxasulfone	84.426	3.780	8667.600	2643.428	1543.900	97.353	12.525	0.099
		Trifluralin	86.286	3.780	14495.600	4420.734	1593.200	97.353	12.175	0.099
Delayed seeding (frost optimum timing TOS2)	Low	Nil	64.336	3.780	20174.799	6152.663	1109.300	97.353	9.975	0.099
		Prosulfocarb	69.051	3.780	9126.399	2783.343	954.900	97.353	9.900	0.099
		Pyroxasulfone	66.445	3.780	2095.600	639.231	873.500	97.353	9.975	0.099
		Trifluralin	69.454	3.780	7026.665	2486.887	867.600	97.353	10.025	0.099
	Optimum	Nil	77.410	3.780	10217.599	3116.116	978.200	97.353	9.950	0.099
		Prosulfocarb	70.737	3.780	2976.000	1053.376	961.000	97.353	9.900	0.099
		Pyroxasulfone	66.547	3.780	4191.199	1834.955	947.400	97.353	10.125	0.099
		Trifluralin	71.116	3.780	3893.599	1187.549	954.900	97.353	10.200	0.099
	High	Nil	71.551	3.780	7588.800	2314.437	1043.900	97.353	10.200	0.099
		Prosulfocarb	67.896	3.780	3794.400	1157.297	1032.300	97.353	10.175	0.099
		Pyroxasulfone	76.973	3.780	1748.400	533.349	924.900	97.353	10.150	0.099
		Trifluralin	71.565	3.780	3174.400	1123.589	941.600	97.353	10.025	0.099
Source of variation	***averaged SED***		***5.345***		***NA***		***134.988***		***0.139***	
Seeding time			<0.001		<0.001		<0.001		<0.001	
Seeding rate			0.006		<0.001		NS		0.033	
Pre-emergent herbicide			0.044		<0.001		NS		0.001	
Seeding time x Seeding rate			NS		NS		NS		NS	
Seeding time x Pre-emergent herbicide			NS		NS		NS		0.006	
Seeding rate x Pre-emergent herbicide			0.048		NS		NS		NS	
Seeding time x Seeding rate x Pre-emergent herbicide			NS		NS		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

Table 5 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Tammin - Part A.

Crop seeding time	Crop seeding rate	Pre-emergent herbicide	Wheat Yield (t/ha)		Crop emergence (plants/m2)		Weed density (plants/m2)		Radiation interception (µmol m-2 s-1)	
			Predicted value	SE	Predicted value	SE	Predicted value	SE	Predicted value	SE
Dry seeded (early TOS1)	Low	Nil	1.329	0.146	109.750	10.243	81.715	15.898	47.098	42.012
		Prosulfocarb	1.528	0.147	112.750	10.243	76.377	17.159	171.800	48.511
		Pyroxasulfone	1.359	0.148	124.250	10.243	14.280	2.778	30.927	48.511
		Trifluralin	1.416	0.147	109.500	10.243	50.967	9.916	80.775	42.012
	Optimum	Nil	1.345	0.147	139.500	10.243	75.231	14.637	194.630	42.012
		Prosulfocarb	1.493	0.146	140.750	10.243	50.831	9.890	148.237	48.511
		Pyroxasulfone	1.324	0.147	145.500	10.243	12.569	2.445	121.587	48.511
		Trifluralin	1.343	0.147	151.750	10.243	45.656	8.883	93.553	42.012
	High	Nil	1.279	0.147	157.250	10.243	59.523	11.581	113.863	42.012
		Prosulfocarb	1.329	0.147	175.250	10.243	32.660	6.354	65.773	42.012
		Pyroxasulfone	1.431	0.147	158.500	10.243	7.517	1.462	107.275	42.012
		Trifluralin	1.292	0.147	157.500	10.243	33.306	6.480	63.880	48.511
Delayed seeding (frost optimum timing TOS2)	Low	Nil	1.227	0.158	134.500	10.243	45.999	8.950	788.393	42.012
		Prosulfocarb	1.387	0.157	143.500	10.243	30.742	5.981	701.028	42.012
		Pyroxasulfone	1.453	0.157	146.250	10.243	7.200	1.401	742.375	42.012
		Trifluralin	1.336	0.157	124.750	10.243	26.686	5.192	676.005	42.012
	Optimum	Nil	1.357	0.158	125.500	10.243	31.399	6.109	754.300	42.012
		Prosulfocarb	1.359	0.159	142.250	10.243	16.637	3.237	710.983	42.012
		Pyroxasulfone	1.211	0.157	134.750	10.243	2.783	0.541	795.633	42.012
		Trifluralin	1.353	0.159	131.750	10.243	9.804	1.908	716.705	42.012
	High	Nil	1.107	0.158	138.750	10.243	21.134	4.112	759.328	42.012
		Prosulfocarb	1.300	0.159	150.750	10.243	7.168	1.395	715.533	42.012
		Pyroxasulfone	1.261	0.158	135.500	10.243	3.027	0.589	757.608	42.012
		Trifluralin	1.205	0.158	114.750	10.243	7.746	1.507	727.295	42.012
Source of variation	***averaged SED***		***0.170***		***14.486***		***NA***		***61.442***	
Seeding time			NS		NS		<0.001		<0.001	
Seeding rate			0.009		<0.001		<0.001		NS	
Pre-emergent herbicide			0.025		NS		<0.001		NS	
Seeding time x Seeding rate			NS		<0.001		0.009		NS	
Seeding time x Pre-emergent herbicide			NS		NS		NS		NS	
Seeding rate x Pre-emergent herbicide			NS		NS		NS		NS	
Seeding time x Seeding rate x Pre-emergent herbicide			NS		NS		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

Table 6 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Tammin --- Part B.

Crop seeding time	**Crop seeding rate**	**Pre-emergent herbicide**	**Radiation interception (%)**		**Seed Production ARG (Seeds/m2)**		**Biomass Wheat (g/m2)**		**Protein %**	
			Predicted value	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**
Dry seeded (early TOS1)	Low	Nil	12.417	5.092	47364.487	7759.047	698.900	86.204	16.300	0.501
		Prosulfocarb	25.717	5.092	43659.318	5163.221	859.600	86.204	15.550	0.501
		Pyroxasulfone	8.322	5.092	8082.771	955.881	812.000	86.204	16.075	0.501
		Trifluralin	18.017	5.092	32924.983	3893.761	725.400	86.204	16.100	0.501
	Optimum	Nil	35.842	5.092	40683.627	4811.311	658.200	86.204	15.175	0.501
		Prosulfocarb	21.962	5.092	29003.448	3429.994	724.800	86.204	14.525	0.501
		Pyroxasulfone	19.100	5.092	7654.286	905.208	781.000	86.204	15.400	0.501
		Trifluralin	19.435	5.092	25413.327	3005.421	686.133	99.539	14.675	0.501
	High	Nil	23.685	5.092	32809.651	3880.122	759.600	86.204	14.775	0.501
		Prosulfocarb	15.240	5.092	21584.203	2552.582	799.300	86.204	15.175	0.501
		Pyroxasulfone	21.745	5.092	3181.198	429.981	650.267	99.539	14.650	0.501
		Trifluralin	12.339	5.092	25434.734	3007.952	774.600	86.204	15.625	0.501
Delayed seeding (frost optimum timing TOS2)	Low	Nil	67.926	5.092	32208.188	3808.992	771.900	86.204	14.750	0.501
		Prosulfocarb	60.049	5.092	22286.781	2635.670	846.000	86.204	14.750	0.501
		Pyroxasulfone	65.126	5.092	1332.692	157.606	785.500	86.204	14.150	0.501
		Trifluralin	57.768	5.092	18296.298	2163.749	749.600	86.204	15.075	0.501
	Optimum	Nil	66.082	5.092	26881.323	3179.028	784.000	86.204	15.000	0.501
		Prosulfocarb	61.212	5.092	14130.445	1671.089	681.000	86.204	14.725	0.501
		Pyroxasulfone	70.208	5.092	2939.627	347.645	695.400	86.204	15.225	0.501
		Trifluralin	60.975	5.092	11927.453	1410.560	717.500	86.204	14.250	0.501
	High	Nil	63.381	5.092	19491.524	2305.099	688.800	86.204	14.775	0.501
		Prosulfocarb	62.141	5.092	10418.059	1232.056	625.800	86.204	14.750	0.501
		Pyroxasulfone	62.287	5.092	1296.140	153.284	762.700	86.204	14.625	0.501
		Trifluralin	66.360	5.092	9857.127	1165.720	688.800	86.204	14.925	0.501
Source of variation	***averaged SED***		***7.201***		***NA***		***123.592***		***0.708***	
Seeding time			<0.001		<0.001		NS		0.006	
Seeding rate			NS		<0.001		NS		NS	
Pre-emergent herbicide			NS		<0.001		NS		NS	
Seeding time x Seeding rate			NS		NS		NS		0.042	
Seeding time x Pre-emergent herbicide			NS		<0.001		NS		NS	
Seeding rate x Pre-emergent herbicide			NS		<0.001		NS		NS	
Seeding time x Seeding rate x Pre-emergent herbicide			NS		0.005		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura 118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

Table 7 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Pingelly --- Part A.

Crop seeding time	Crop seeding rate	Pre-emergent herbicide	Wheat Yield (t/ha)		Crop emergence (plants/m2)		Weed density (plants/m2)		Radiation interception (µmol m-2 s-1)	
			Predicted value	SE	Predicted value	SE	Predicted value	SE	Predicted value	SE
Dry seeded (early TOS1)	Low	Nil	4.484	0.204	131.000	11.719	11.120	7.116	*NA*	*NA*
		Prosulfocarb	4.890	0.196	123.795	10.149	8.295	4.598	*NA*	*NA*
		Pyroxasulfone	4.879	0.195	110.040	10.149	2.295	1.459	*NA*	*NA*
		Trifluralin	4.740	0.196	127.725	10.149	2.295	1.459	*NA*	*NA*
	Optimum	Nil	4.860	0.198	127.725	10.149	11.340	6.187	*NA*	*NA*
		Prosulfocarb	5.029	0.197	112.005	10.149	7.045	3.946	*NA*	*NA*
		Pyroxasulfone	5.158	0.198	123.795	10.149	4.590	2.663	*NA*	*NA*
		Trifluralin	5.184	0.199	123.795	10.149	8.135	4.515	*NA*	*NA*
	High	Nil	4.897	0.196	165.060	10.149	11.885	6.471	*NA*	*NA*
		Prosulfocarb	5.307	0.196	168.990	10.149	5.250	3.008	*NA*	*NA*
		Pyroxasulfone	5.065	0.198	143.445	10.149	2.295	1.459	*NA*	*NA*
		Trifluralin	5.225	0.197	143.445	10.149	4.590	2.663	*NA*	*NA*
Delayed seeding (frost optimum timing TOS2)	Low	Nil	3.951	0.194	131.500	10.149	3.750	2.223	*NA*	*NA*
		Prosulfocarb	3.957	0.194	113.000	10.149	1.250	0.903	*NA*	*NA*
		Pyroxasulfone	4.032	0.196	132.250	10.149	1.000	0.768	*NA*	*NA*
		Trifluralin	3.868	0.192	124.500	10.149	2.000	1.303	*NA*	*NA*
	Optimum	Nil	4.097	0.195	144.000	10.149	6.500	3.661	*NA*	*NA*
		Prosulfocarb	3.948	0.194	136.750	10.149	2.750	1.698	*NA*	*NA*
		Pyroxasulfone	4.019	0.194	134.250	10.149	1.000	0.768	*NA*	*NA*
		Trifluralin	4.197	0.193	129.000	10.149	1.250	0.903	*NA*	*NA*
	High	Nil	4.033	0.194	138.750	10.149	2.000	1.303	*NA*	*NA*
		Prosulfocarb	4.090	0.192	143.750	10.149	2.000	1.303	*NA*	*NA*
		Pyroxasulfone	4.047	0.198	144.000	10.149	1.000	0.768	*NA*	*NA*
		Trifluralin	3.918	0.192	145.750	10.149	0.750	0.630	*NA*	*NA*
Source of variation	***averaged SED***		***0.223***		***14.452***		**-**		*NA*	
Seeding time			0.007		NS		<0.001		*NA*	
Seeding rate			<0.001		<0.001		NS		*NA*	
Pre-emergent herbicide			0.040		NS		0.002		*NA*	
Seeding time x Seeding rate			0.017		0.040		NS		*NA*	
Seeding time x Pre-emergent herbicide			0.019		NS		NS		*NA*	
Seeding rate x Pre-emergent herbicide			NS		NS		NS		*NA*	
Seeding time x Seeding rate x Pre-emergent herbicide			NS		NS		NS		*NA*	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha). NA – Data not collected at this site due to unfavourable cloud conditions.

Table 8 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Pingelly --- Part B.

Crop seeding time	Crop seeding rate	Pre-emergent herbicide	Radiation interception (%)		Seed Production ARG (Seeds/m2)		Biomass Wheat (g/m2)		Protein %	
			Predicted value	SE	Predicted value	SE	Predicted value	SE	Predicted value	SE
Dry seeded (early TOS1)	Low	Nil	NA	NA	33024.863	20390.590	1597.333	110.075	10.327	0.281
		Prosulfocarb	NA	NA	10545.051	5566.229	1668.400	95.328	10.500	0.245
		Pyroxasulfone	NA	NA	8987.933	4744.342	1792.500	95.328	10.175	0.245
		Trifluralin	NA	NA	24801.266	13091.024	1561.867	110.075	9.975	0.245
	Optimum	Nil	NA	NA	30642.861	16174.368	1719.300	95.328	10.025	0.245
		Prosulfocarb	NA	NA	19978.392	10545.388	1931.200	110.075	10.100	0.245
		Pyroxasulfone	NA	NA	6430.208	3394.309	1696.900	95.328	10.175	0.245
		Trifluralin	NA	NA	9864.098	5206.804	1616.300	95.328	9.925	0.245
	High	Nil	NA	NA	51788.010	40211.688	1672.600	95.328	9.800	0.245
		Prosulfocarb	NA	NA	11850.745	6255.407	1752.600	95.328	9.925	0.245
		Pyroxasulfone	NA	NA	6174.885	3259.543	1703.300	95.328	9.975	0.245
		Trifluralin	NA	NA	13673.652	7217.584	1942.100	95.328	9.925	0.245
Delayed seeding (frost optimum timing TOS2)	Low	Nil	NA	NA	11769.424	6212.484	1282.900	95.328	10.125	0.245
		Prosulfocarb	NA	NA	3835.755	2024.890	1282.900	95.328	9.875	0.245
		Pyroxasulfone	NA	NA	3043.063	1606.487	1217.600	95.328	9.950	0.245
		Trifluralin	NA	NA	3206.976	3815.178	1064.300	95.328	10.325	0.245
	Optimum	Nil	NA	NA	13600.023	7178.721	1267.300	95.328	9.725	0.245
		Prosulfocarb	NA	NA	7086.936	3740.947	1140.500	95.328	10.600	0.245
		Pyroxasulfone	NA	NA	967.360	751.615	1302.600	95.328	9.725	0.245
		Trifluralin	NA	NA	3170.075	2461.989	1275.300	95.328	10.075	0.245
	High	Nil	NA	NA	5088.190	2685.957	1146.200	95.328	10.100	0.245
		Prosulfocarb	NA	NA	1108.656	585.457	1255.100	95.328	10.300	0.245
		Pyroxasulfone	NA	NA	672.177	415.361	1112.600	95.328	10.200	0.245
		Trifluralin	NA	NA	3614.631	2232.091	1133.100	95.328	10.075	0.245
Source of variation	NA		NA		**-**		***137.594***		***0.341***	
Seeding time			NA		<0.001		<0.001		NS	
Seeding rate			NA		NS		NS		NS	
Pre-emergent herbicide			NA		<0.001		NS		NS	
Seeding time x Seeding rate			NA		NS		NS		NS	
Seeding time x Pre-emergent herbicide			NA		NS		NS		NS	
Seeding rate x Pre-emergent herbicide			NA		NS		NS		NS	
Seeding time x Seeding rate x Pre-emergent herbicide			NA		NS		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha). NA – Data not collected at this site due to unfavourable cloud conditions.

Table 9 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Optimum crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Dandaragan.

Crop seeding time	Crop seeding rate	Pre-emergent herbicide	Wheat Yield (t/ha)		Crop emergence (plants/m2)		Weed density (plants/m2)		Radiation interception (µmol m-2 s-1)		Radiation interception (%)		Seed Production ARG (Seeds/m2)		Biomass Wheat (g/m2)		Protein %	
			Predicted value	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**
Dry seeded (early TOS1)	Optimum	Nil	3.040	0.153	128.000	5.442	20.500	10.962	884.463	51.067	86.516	4.406	69948.400	19911.746	1392.000	88.866	11.975	0.108
		Prosulfocarb	3.268	0.153	135.250	5.442	7.000	3.922	798.063	51.067	75.140	4.406	26139.200	7440.964	1461.700	88.866	12.175	0.108
		Pyroxasulfone	3.365	0.153	116.500	5.442	4.000	2.354	859.005	51.067	80.704	4.406	6832.400	1945.066	1496.300	88.866	12.400	0.108
		Trifluralin	3.385	0.153	123.000	5.442	11.000	6.009	860.023	51.067	79.277	4.406	28197.600	8026.910	1501.300	88.866	12.275	0.108
		Luximax	3.170	0.125	118.000	4.444	7.500	3.363	831.883	41.696	78.321	3.597	21369.333	4945.246	1603.933	72.559	12.233	0.089
		Mateno	3.440	0.125	116.500	4.444	12.500	5.464	809.530	41.696	78.080	3.597	8663.467	2004.951	1570.467	72.559	12.483	0.089
		Overwatch	3.392	0.125	126.333	4.444	12.667	5.534	792.728	41.696	76.015	3.597	9002.400	2083.385	1562.400	72.559	12.300	0.089
Delayed seeding (frost optimum timing TOS2)	Optimum	Nil	3.350	0.153	138.500	5.442	7.750	4.314	472.883	51.067	77.410	4.406	10217.600	2908.701	978.200	88.866	9.950	0.108
		Prosulfocarb	3.237	0.153	136.750	5.442	6.500	3.661	508.362	51.067	70.737	4.406	2976.000	982.650	961.000	88.866	9.900	0.108
		Pyroxasulfone	3.376	0.153	135.750	5.442	0.000	0.000	509.735	51.067	66.547	4.406	4191.200	1709.642	947.400	88.866	10.125	0.108
		Trifluralin	3.439	0.153	132.250	5.442	1.750	1.170	519.385	51.067	71.116	4.406	3893.600	1108.503	954.900	88.866	10.200	0.108
		Luximax	3.303	0.125	137.833	4.444	2.833	1.397	522.143	41.696	74.797	3.597	6745.600	1561.133	990.800	72.559	10.100	0.089
		Mateno	3.288	0.125	134.000	4.444	2.333	1.184	481.260	41.696	70.030	3.597	3779.520	959.912	1074.533	72.559	10.117	0.089
		Overwatch	3.298	0.125	136.167	4.444	5.167	2.382	512.980	51.067	72.231	3.941	4850.880	1231.976	994.800	72.559	10.083	0.089
Source of variation	***averaged SED***		***0.201***		***7.126***		***NA***		***67.785***		***5.801***		***NA***		***116.353***		***0.142***	
Seeding time			NS		<0.001		<0.001		<0.001		0.002		<0.001		<0.001		<0.001	
Pre-emergent herbicide			NS		NS		NS		NS		NS		<0.001		NS		0.018	
Seeding time x Pre-emergent herbicide			NS		NS		NS		NS		NS		0.013		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

Table 10 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Optimum crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Tammin.

Crop seeding time	**Crop seeding rate**	**Pre-emergent herbicide**	**Wheat Yield (t/ha)**		**Crop emergence (plants/m2)**		**Weed density (plants/m2)**		**Radiation interception (µmol m-2 s-1)**		**Radiation interception (%)**		**Seed Production ARG (Seeds/m2)**		**Biomass Wheat (g/m2)**		**Protein %**	
			Predicted value	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**
Dry seeded (early TOS1)	Optimum	Nil	1.388	0.163	139.500	8.006	75.230	12.570	194.630	46.891	35.842	6.242	40683.627	5987.470	658.200	96.578	15.175	0.474
		Prosulfocarb	1.321	0.188	122.667	9.244	50.831	8.493	148.237	54.145	21.962	6.242	29003.448	4268.481	724.800	96.578	14.525	0.474
		Pyroxasulfone	1.466	0.163	145.500	8.006	12.569	2.100	121.587	54.145	19.100	6.242	7654.286	1126.493	781.000	96.578	15.400	0.474
		Trifluralin	1.455	0.163	151.750	8.006	45.656	7.628	93.553	46.891	19.435	6.242	25413.327	3740.117	686.133	111.519	14.675	0.474
		Luximax	1.361	0.133	132.000	6.537	7.657	1.045	130.244	41.940	21.767	5.096	1559.273	187.370	712.667	78.856	15.267	0.387
		Mateno	1.253	0.133	140.167	6.537	7.306	0.997	173.368	46.891	23.593	5.096	1093.937	143.999	722.333	78.856	15.500	0.387
		Overwatch	1.428	0.133	138.833	6.537	2.994	0.408	112.512	41.940	19.845	5.096	775.824	102.125	770.200	78.856	15.250	0.387
Delayed seeding (frost optimum timing TOS2)	Optimum	Nil	1.219	0.163	125.500	8.006	31.399	5.246	754.300	46.891	66.082	6.242	26881.323	3956.165	784.000	96.578	15.000	0.474
		Prosulfocarb	1.322	0.163	142.250	8.006	16.637	2.780	710.983	46.891	61.212	6.242	14130.445	2079.599	681.000	96.578	14.725	0.474
		Pyroxasulfone	1.107	0.163	134.750	8.006	3.915	0.755	795.633	46.891	70.208	6.242	2939.627	432.629	695.400	96.578	15.225	0.474
		Trifluralin	1.455	0.163	131.750	8.006	9.804	1.638	716.705	46.891	60.975	6.242	11927.453	1755.381	717.500	96.578	14.250	0.474
		Luximax	1.204	0.133	125.500	6.537	4.530	0.618	722.148	38.286	63.291	5.096	484.917	58.270	720.000	78.856	15.067	0.387
		Mateno	1.438	0.133	134.500	6.537	4.095	0.612	771.702	38.286	66.885	5.096	448.005	58.973	822.267	78.856	14.350	0.387
		Overwatch	1.378	0.133	135.500	6.537	2.213	0.370	709.963	38.286	62.355	5.096	276.836	36.441	730.400	78.856	14.800	0.387
Source of variation	***averaged SED***		***0.216***		***10.626***		***NA***		***64.553***		***8.173***		***NA***		***128.194***		***0.621***	
Seeding time			NS		NS		<0.001		<0.001		<0.001		<0.001		NS		NS	
Pre-emergent herbicide			NS		NS		<0.001		NS		NS		<0.001		NS		NS	
Seeding time x Pre-emergent herbicide			NS		NS		0.004		NS		NS		NS		NS		NS	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

Table 11 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of Crop seeding time, Optimum crop seeding rate and Residual pre-emergent herbicide choice and the relevant interactions for Site Pingelly.

Crop seeding time	**Crop seeding rate**	**Pre-emergent herbicide**	**Wheat Yield (t/ha)**		**Crop emergence (plants/m2)**		**Weed density (plants/m2)**		**Radiation interception (µmol m-2 s-1)**		**Radiation interception (%)**		**Seed Production ARG (Seeds/m2)**		**Biomass Wheat (g/m2)**		**Protein %**	
			Predicted value	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**	**Predicted value**	**SE**
Dry seeded (early TOS1)	Optimum	Nil	4.925	0.204	127.725	9.318	11.340	1.690	*NA*	*NA*	*NA*	*NA*	30206.400	15740.695	1719.300	86.740	10.025	0.198
		Prosulfocarb	5.175	0.204	112.005	9.318	7.045	1.335	*NA*	*NA*	*NA*	*NA*	19058.800	9931.733	1931.200	100.159	10.100	0.198
		Pyroxasulfone	4.975	0.204	123.795	9.318	4.590	1.081	*NA*	*NA*	*NA*	*NA*	6733.200	3508.921	1696.900	86.740	10.175	0.198
		Trifluralin	5.125	0.204	123.795	9.318	8.135	1.433	*NA*	*NA*	*NA*	*NA*	10155.600	5292.317	1616.300	86.740	9.925	0.198
		Luximax	4.933	0.167	137.550	7.608	0.000	0.000	*NA*	*NA*	*NA*	*NA*	6580.267	2761.850	1753.267	70.823	9.917	0.161
		Mateno	5.250	0.167	161.916	8.335	0.000	0.000	*NA*	*NA*	*NA*	*NA*	2389.067	1002.873	1695.800	70.823	10.017	0.161
		Overwatch	5.100	0.167	128.380	7.608	0.000	0.000	*NA*	*NA*	*NA*	*NA*	1173.867	716.355	1777.333	70.823	10.317	0.161
Delayed seeding (frost optimum timing TOS2)	Optimum	Nil	4.250	0.204	144.000	9.318	6.500	1.283	*NA*	*NA*	*NA*	*NA*	13925.200	7256.638	1267.300	86.740	9.725	0.198
		Prosulfocarb	3.725	0.204	136.750	9.318	2.750	0.842	*NA*	*NA*	*NA*	*NA*	7204.400	3754.461	1140.500	86.740	10.600	0.198
		Pyroxasulfone	4.300	0.204	134.250	9.318	1.000	0.521	*NA*	*NA*	*NA*	*NA*	892.800	685.690	1302.600	86.740	9.725	0.198
		Trifluralin	4.150	0.204	129.000	9.318	1.250	0.578	*NA*	*NA*	*NA*	*NA*	3000.800	2303.629	1275.300	86.740	10.075	0.198
		Luximax	4.250	0.167	133.167	7.608	1.667	0.536	*NA*	*NA*	*NA*	*NA*	1587.200	968.473	1323.867	70.823	9.650	0.161
		Mateno	4.517	0.167	135.333	7.608	0.833	0.385	*NA*	*NA*	*NA*	*NA*	5009.600	2610.761	1359.600	70.823	9.450	0.161
		Overwatch	4.533	0.167	129.500	7.608	0.000	0.000	*NA*	*NA*	*NA*	*NA*	2529.600	1318.445	1372.467	70.823	9.567	0.161
Source of variation	***averaged SED***		***0.268***		***12.268***		***NA***		***NA***		***NA***		***NA***		***115.136***		***0.259***	
Seeding time			<0.001		NS		<0.001		*NA*		*NA*		0.041		<0.001		0.004	
Pre-emergent herbicide			NS		NS		<0.001		*NA*		*NA*		<0.001		NS		0.044	
Seeding time x Pre-emergent herbicide			NS		NS		<0.001		*NA*		*NA*		NS		NS		0.022	

NS – Not significant, Nil (knockdown only), Trifluralin (2.0 L/ha), Prosulfocarb 2000 + s-metolachlor (Boxer Gold) (2.5L), Pyroxasulfone 100 (Sakura) (118g), Bixlozone (Isoxazolidinone) 400 g/L (Overwatch ® 1.25 L/ha), Cinmethylin 750g/L (Luximax® 500mL/ha), Aclinofen + others TBA (Mateno® 1 L/ha).

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