2022 EP Frost Project Results

Frost events causing extensive crop damage and financial loss were experienced in large areas of Central and Eastern Eyre Peninsula in the four years to 2022. Anecdotal evidence indicated that even late in the growing season crops on Eyre Peninsula could suffer damage from frost events which reduced yields. As a result, growing longer season varieties that flower later to avoid frost can't always be relied on as an effective management strategy to mitigate frost risk. This project aimed to;

1. Demonstrate the effectiveness of a range of frost management strategies to mitigate yield penalties due to frost damage on representative frost prone site on Eyre Peninsula.

2. Help improve the understanding of Eyre Peninsula growers of the causes of frost damage in the region and strategies to mitigate this risk.

Selection of demonstration site and establishment of groups.

In consultation with the project steering committee a demonstration site where relatively consistent frost damage had been observed in crops in the five years to 2022 was selected on Tim Zacher's property east of Tooligie (Figure 1).

Historical production records were used identify two areas of different frost risk (high and moderate) within the paddock to demonstrate effectiveness of different frost management strategies. The rest of the paddock was sown with wheat in 2021 and barley in 2022.

Several discussion groups (made up of growers that have been severely affected by frost in multiple seasons) were established to review the results from the demonstration site and landholder observations on their own properties.

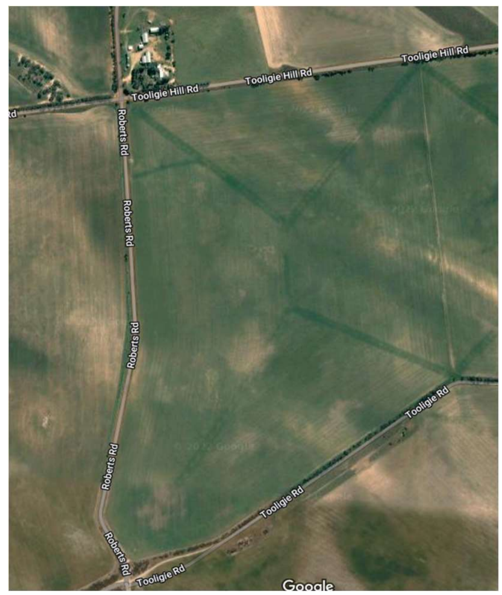

Figure 1. Main trial site paddock at Tim Zacher's, Tooligie Hill Road.

Site Establishment

Several demonstration trials were established in early 2022 which included;

- Trial 1: Phenology
- Trial 2: Mixtures
- Trial 3: Nutrition
- Demonstration: Bednar Ripper

Each of these trials were established as paired demonstrations sited in both a low and high frost risk zone within the paddock (Figure 2).

Additionally, a soil amelioration strip using a Bednar ripper was implemented which ran across the two frost risk zones (Figures 2 and 3). This soil amelioration treatment aimed to determine if soil modification practices such as ripping and topsoil mixing, using implements such as a Bednar ripper, can influence mitigating frost damage.

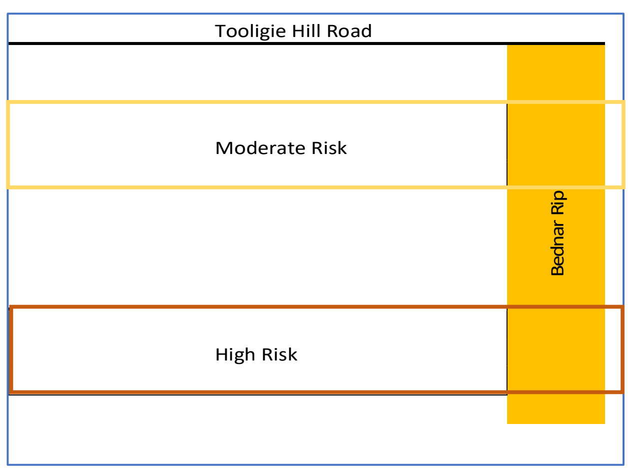

Figure 2. Site layout within the paddock.

Figure 3. Ripping with Bednar machine at Tim Zacher's, main trial site Tooligie, Autumn 2022.

Canopy Temperatures

Temperature sensors were placed at crop canopy height within both the ripped and unripped areas on each frost risk zone to record frost events as they occurred (Figures 4 and 5). Results showed that during critical frost risk window (GS31 at 12 August 2022) to 30 September 2022, no temperatures below 0°C were recorded in the moderate risk zone (either on the ripped or unripped areas) whilst below 0°C temperatures were recorded in the high-risk zone on several occasions.

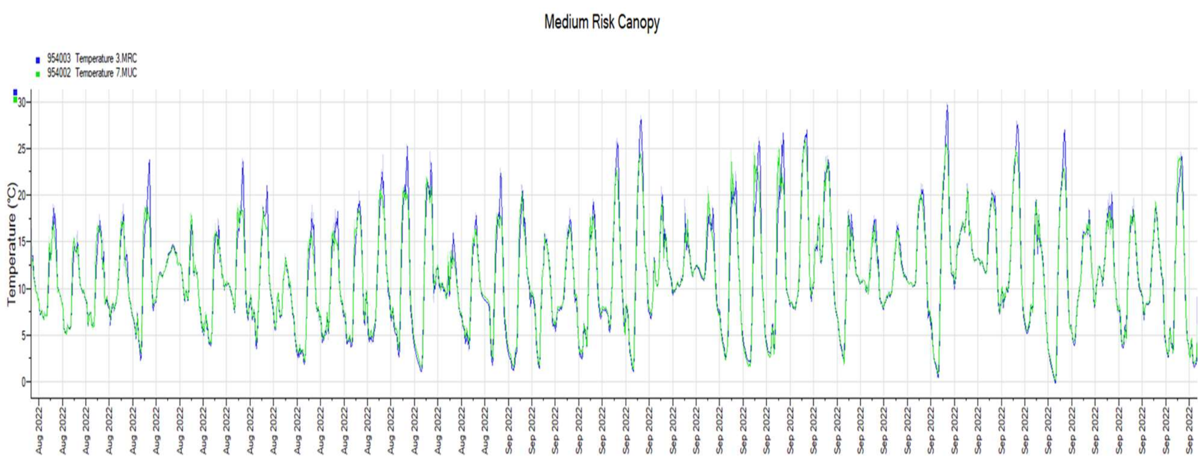

Figure 4. In canopy temperatures in ripped (MRC) and unripped (MUC) areas of the medium frost risk zone, Tooligie 2022.

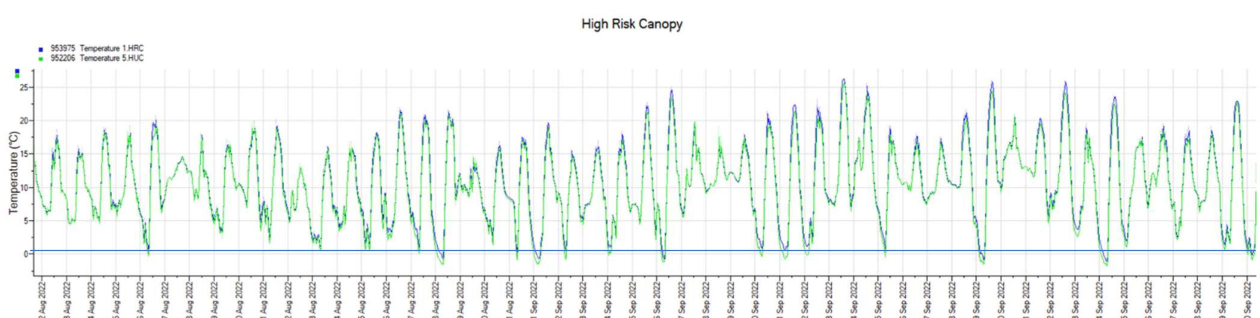

Figure 4. In canopy temperatures in ripped (MRC) and unripped (MUC) areas of the high frost risk zone, Tooligie 2022.

Pre-season Soil Test

Pre-season soil tests revealed a sandy topsoil over a gradational loam on the moderate risk zone (Table 1). Boron and salinity levels increase with increasing depths from 60 cm. The high-risk site had significantly higher surface water repellence (MED 2.0) with elevated salt and boron (18 mg/kg) starting at 40 cm below the soil surface. Nutrition levels were generally high with high amounts of available phosphorus.

Table 1. Pre-season soil analysis to 1 m.

SampleName	Sample Depth	pH 1:5 water	pH CaCl2	Organic Carbon (W&B)	Colour	MIR - Aus Soil Texture	Nitrate - N (2M KCl)	Ammonium - N (2M KCl)	Colwell Phosphorus	PBI + Col P	DGT-P	MED	KCl Sulfur (S)	Salinity EC 1:5	Ece	Boron	Iron (Fe)	Manganese (Mn)	Copper (Cu)	Zinc (Zn)	TDS	MIR - Clay	MIR - Sand	MIR - Silt
		pH units	pH units	% (40°C)			mg/kg	mg/kg	mg/kg		µg/L		mg/kg	dS/m	dS/m	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/L	%	%	%
Medium Risk	0-10	7.35	6.91	1.47	brown	Sand	1.3	4	68	42	174	0.0	5.3	0.18	4.1	0.54	62	17	0.37	4	110	4.6	90.1	5.3
Medium Risk	10-20	7.97	7.47			loam	2.3	<1						0.23	1.9	2					150	25.9	62.1	12
Medium Risk	20-40	8.49	7.86			loam	2.5	<1						0.2	1.8	3.2					130	31.5	50.2	18.3
Medium Risk	40-60	9.37	8.27			loam	1.5	<1						0.34	2.9	5.1					220	29.7	50.1	20.2
Medium Risk	60-80	9.73	8.66			loam	3.5	<1						0.66	5.7	14					420	35.6	45	19.4
Medium Risk	80-100	9.7	8.7			loam	3.6	<1						0.98	8.4	17					630	31.4	50.8	17.8
High Risk	0-10	6.03	5.22	0.94	brown	Sand	17	46	67	22	694	2.0	15	0.1	2.3	0.55	35	6.7	0.33	2.7	65	5.3	90.6	4.1
High Risk	10-20	6.43	5.62			loam	3.2	19						0.049	0.69	0.32					32	8.7	90.6	<1
High Risk	20-40	8.96	8.16			loam	4	2.3						0.38	5.4	5.9					250	20.4	69.7	9.9
High Risk	40-60	9.25	8.48			Clay	3.2	1.9						0.95	5.5	18					610	36.6	45.3	18.2
High Risk	60-80	9.27	8.49			loam	48	2.8						1.3	11	13					830	32.3	54.4	13.3
High Risk	80-100	9.38	8.54			loam	3	1.3						1.1	9.1	12					670	26.7	63.9	9.5

Trial 1: Crop Phenology

Aim: to determine if time of sowing coupled with plant phenology can help mitigate frost damage.

Historically, it was considered that planting later or using longer season varieties could help mitigate the impact of frosts on crop yields. However, damaging frosts close to crop maturity have been experienced regularly in recent years, reducing the effectiveness of this 'avoidance' method. The trial used different crop types and varieties with different phenology (development) speed (Table 2) and two different sowing times (TOS1: 19 April, TOS2: 18 May) to try and mitigate the damage from these late frosts.

Results show that on the moderate frost risk zone (which did not record temperatures below 0°C), in most cases the yield difference between sowing times was less than 15% (around 0.5 t/ha), with early sowing (TOS1) benefitting the quicker maturing varieties but penalising the slower maturing varieties. In 2022 yields on the high frost risk zone were significantly less than those in the zone which did not get frosted, ranging from 12 to 100% reduction in yield. The best strategy in the high-risk zone in 2022 was early sown barley yielding 75% to 88% of that achieved in the moderate risk zones. In the high-risk zone long season wheats sown late (TOS2) yielded better than TOS1 (and yielded 54 to 62% of the relative yield from the moderate risk zone), presumably missing the frost at critical development times. The yield of quicker maturing wheats in this zone was severely reduced regardless of sowing time.

Table 2. Varieties trialled, relative development speed and flowering date at Tooligie site in 2022.

			Flowering Date			
			TOS1		TOS2	
Crop	Variety	Phenology	Moderate Risk	High risk	Moderate risk	High Risk
Wheat	Vixen	V. Fast	7-Aug	8-Aug	18-Sep	18-Sep
	Calibre	Fast	23-Aug	25-Aug	21-Sep	24-Sep
	Scepter	Fast-Medium	23-Aug	-	23-Sep	25-Sep
	Rockstar	Medium	23-Aug	26-Aug	26-Sep	26-Sep
	Denison	Slow	10-Sep	10-Sep	29-Sep	29-Sep
	Longsword	Fast Winter	23-Sep	26-Sep	4-Oct	4-Oct
	Bennett	Long winter	14-Oct	14-Oct	-	-
Barley	Commodus	Fast	25-Aug	23-Aug	10-Sep	10-Sep
	Spartacus	V. Fast	8-Aug	8-Aug	15-Sep	17-Sep
	Planet	Fast-Medium	-	21-Aug	23-Sep	-

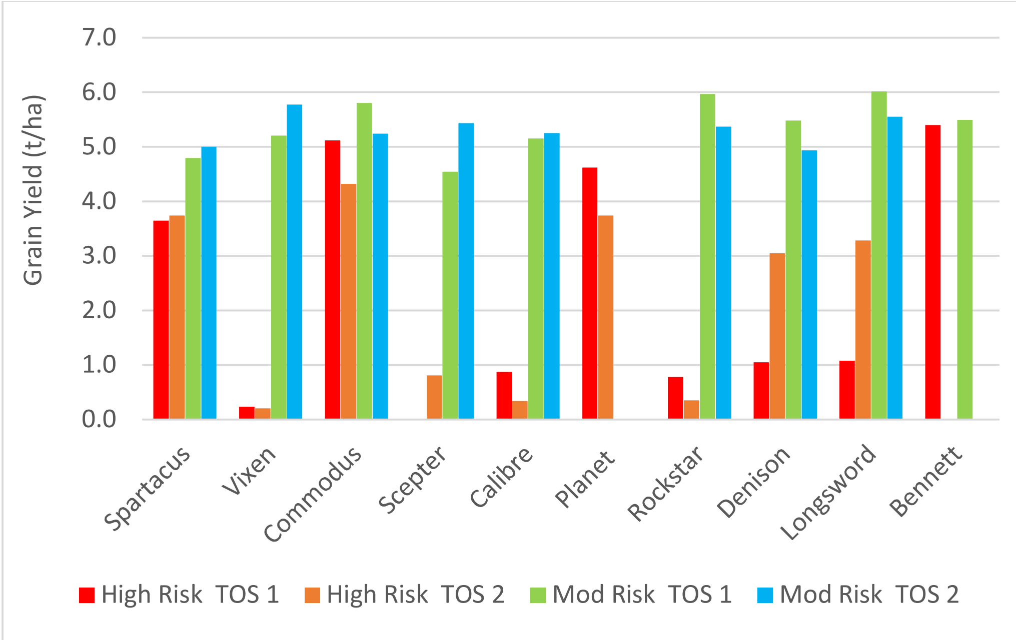

Figure 5 Grain yield of different wheat and barley varieties sown at Tooligie in 2022

Key Results

- The high-risk zone experienced frost damage in most of the wheat varieties at both times of sowing leading to very low yields.
- Winter wheat Bennett didn't appear to suffer any yield loss due to frost.
- Barley varieties: Spartacus, Commodus and Planet experienced less frost damage in the high-risk zone compared to the wheat varieties and yielded higher.

Trial 2: Varietal Mixtures

Aim: To determine if mixing varieties with different development times has the potential to reduce risk of frost damage.

Several treatments of different cereal varieties were trialled both for wheat and barley (Table 3). Thought was given to choosing varieties which fall within the same quality classification to facilitate delivery at harvest.

Table 3. Cereal mixtures trialled.

Wheat Mixtures	Denison/Vixen
	Denison/Calibre
	Denison/Rockstar
	Vixen/Calibre
	Vixen/Rockstar
	Dension/Calibre/Vixen
Barley Mixtures	Spartacus/Commodus
	Spartacus/Planet

Results reflected those from the variety/phenology trial with severely reduced wheat yields on the high-risk zone (for both TOS) compared to the moderate frost risk zone. The yields of barley mixtures were much less impacted by frost in this zone (Figure 6).

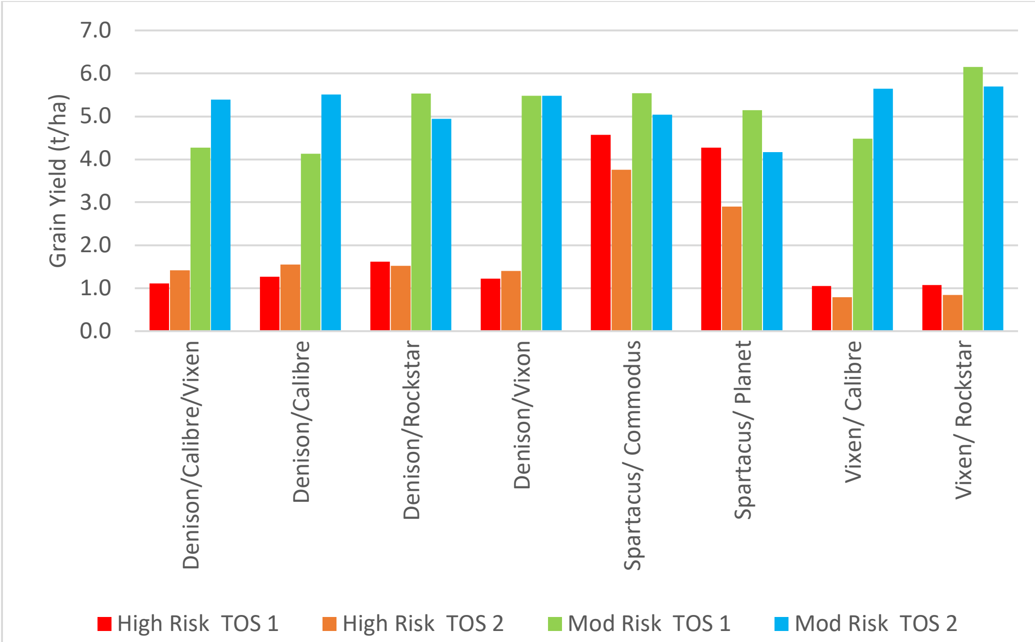

Figure 6. Grain yield of different wheat and barley variety mixtures sown at Tooligie in 2022

Key Results:

- Similarly to the phenology experiment, most of the wheat variety mixtures yielded poorly in the high-risk zone. However, when sown alone in TOS 1 of the phenology trial Vixen only yielded 0.24t/ha, but when included as part of a mixture in this experiment the treatment yielded just over 1t/ha.
- Mixtures containing barley yielded higher than mixtures containing wheat.

Trial 3 Crop Nutrition and manipulation

Trial 3. Crop Nutrition - aimed to determine if the application of nutrition treatments/ antibacterial treatments has any beneficial response to reducing frost damage and improving wheat yield, it also contained treatments aimed to manipulate crop development through the application of plant hormones or taking out the growing tip of plants.

Recent work in Western Australia suggests applications of potassium (K) and/ or copper (Cu) can help reduce the impact of frost. However, this typically this occurs where these elements are deficient. Soil test data prior to the season suggests that copper levels were adequate. Several different formulations of copper and potassium, as well as nitrogen (N) and zinc (Zn) and other trace element (TE) products were trialled at the site (Table 4). Additionally, there was some interest in trialling novel products which might be effective in mitigating frost risk and/or crop damage. Such products included a range of anti-bacterial products designed to disrupt ice nucleating bacteria as well as several growth stimulants/protectants.

Table 4. Nutrient, antibacterial, and other growth treatments applied on site in 2022.

Mineral Nutrients	**Antibacterial**	**Other Growth stimulants/protectants**
• Copper (Cu) • Foliar Potassium (K) • Chelated Cu (Kestrel) • Nitrogen (N) • Potash (K) • Potash K+ Cu • Triple trace (Cu, Zn, Mn) • Zn + Cu	• Antibacterial - Seaweed • Antibacterial - Smoke	• Plant stress product • Seaweed concentrate • TE to increase plant sugars applied as foliar. • TE to increase plant sugars applied on seed. • Y-Polyglutamaic acid * NB. Treatments also incorporated a defoliation treatment to manipulate crop maturity (Trial 4).

Treatments were applied GS 43 and 59. On the moderate risk zone (which did not record a frost in the critical growth period) grain yields ranged from 4.84 t/ha on the treatment which was manually defoliated during the season to 6.56 t/ha on the nitrogen treatment (and the nil control yielding 5.89 t/ha) (Table 5). However, the differences between treatments were not significant. On the high-risk frost zone grain yields were severely reduced (with the nil control yielding 1.96 t/ha) compared to the moderate risk zone, highlighting the frost impact in this zone, but again the differences between treatments were not significant.

Table 5. Grain yield of nutrient trial on unmodified strips at Tooligie, 2022.

	Yield (t/ha)	
Treatment	High Risk	Mod. Risk
Antibacterial - seaweed	2.15	6.55
Antibacterial - smoke	1.82	6.50
Antitransparent	2.28	5.54
Copper	2.20	5.83
Defoliation	1.75	4.84
K foliar	1.78	6.24
Kestral Cu	2.35	5.62
Nil	1.96	5.89
Nitrogen	2.53	6.56
Plant stress product	1.96	5.73
Potash	2.74	6.24
Potash + Cu	2.78	6.26
Seaweed concentrate	1.85	6.09
Sugar foliar	2.03	5.63
Sugar seed	2.21	5.98
Trace triple	2.60	5.97
Y Polyglutamaic acid	2.58	5.91
Zn + Cu	2.64	6.04
Site mean yield	2.23	5.97
lsd	ns	ns

Several of these products were also applied across the Bednar 'soil amelioration' strip adjacent to the main site. In the high-risk zone data loggers at crop canopy height recorded temperatures in the order of 0.56 to 1.38°C higher on the ameliorated soil compared to the unripped zones (Table 6).

Table 6. Minimum temperatures in high-risk zone 12/08/23 to 30/09/23

	Minimum temperate (°C)		**Difference in temperature Ripped vs Unripped**
Date	**Unripped Control**	**Ripped zone**	**(°C)**
28/08	-1.69	-0.72	0.97
31/08	-1.01	0.08	1.09
1/09	-1.6	-0.89	0.71
2/09	-1.11	0.15	1.26
4/09	-0.23	0.87	1.1
6/09	-1.33	-0.76	0.57
10/09	-0.53	0.73	1.26
11/09	-0.75	0.63	1.38
12/09	-0.19	1.09	1.28
15/09	-0.79	0.51	1.3
19/09	-1.62	-1.06	0.56
24/09	-1.83	-1.17	0.66
30/09	-0.99	-0.29	0.7

There was no significant difference between the grain yield of the ameliorated strip compared to paired unripped strip in the moderate risk zone (Table 7), but yields were significantly higher on the ameliorated strips in the high-risk zone compared to unripped controls (with the ripped nil product treatment yielding 4.56 t/ha).

Table 7. ***Grain yield of nutrient and growth manipulation treatments on modified strips at Tooligie, 2022***

	Yield (t/ha)	
Treatment	High Risk	Mod. Risk
Antibacterial - seaweed	4.26	5.90
Copper	4.12	5.43
Nil	4.56	6.16
Potash + Cu	5.20	5.36
Sugar foliar	4.91	5.72
Trace Triple	4.53	5.83
Site mean yield	4.60	5.73
lsd	0.42	ns

Key Results

- The moderate risk zone had warmer temperatures than the high-risk zone at night.
- On the Bednar ripped strips temperatures were warmer resulting in less frost events and less time below zero.
- As a result of this the most severe frost damage occurred on the unripped part of the high-risk zone with the least frost damage on ripped areas in the moderate frost risk area.
- No significant yield improvement was achieved through the addition of any of the products applied.
- Treatments where potassium was applied had higher overall yields which warrants further investigation.
- Grain yields in the high-risk zone were higher where the soil was ripped compared to un-ripped (4.6t/ha compared to 0.8 t/ha, but similar in the moderate risk zone 5.7 t/ha compared to 5.4 t/ha).

Key project takeaways so far:

- In high risk areas (that consistently get frosted) growing wheat varieties with early, medium or late flowering time won't escape frost damage.
- Barley yield consistently appears less damaged by frost in high risk areas.
- There is no magic solution to controlling frost. Applying nutrients, where deficient will aid crop growth, but having levels above thresholds won't reduce damage from frost.
- The role that ice nucleating bacteria has on frost severity and how it can be manipulated is not well understood and requires further research.
- Soil amelioration appears to reduce frost damage by improving in-canopy temperatures during frost events, but the mechanisms driving this aren't yet understood.

This project is continuing in 2023.

Acknowledgements

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