Use of chemical protective products to change the ability of wheat to tolerate frost

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Abstract
Frost is a large issue limiting cereal production across the Australian wheat-belt. Successful frost risk management requires an integrated approach involving many aspects of the farming system, such as sowing time, crop/cultivar selection, stubble management and plant nutrition. A number of commercial chemical products have become available in recent times that reputedly protect crops from frost damage. During 2014 at Mintaro, South Australia, four protectant products (anti-transpirant and biochemical products) were applied and one plant growth regulator, trinexapac-ethyl, to wheat plots sown at seven weekly intervals to assess their potential to alleviate frost damage. Several frost events occurred during the growing season. The degree of frost damage varied across each time of sowing corresponding to frost events at susceptible stages of plant development. Of the chemical protectants tested, none provided any significant reduction in frost induced sterility or gains in yield compared with the untreated control. However, trinexapac-ethyl increased the sensitivity of wheat to frost. Average frost induced sterility increased from 42% of the untreated control to 51% when applied during stem elongation. This difference in sterility was also reflected in grain yield as the same treatment was 8% lower yielding than untreated plots. Preliminary results of this study suggested none of the tested chemical anti-transpirant or biochemical products offered any significant improvement in frost tolerance.

Key words
Frost, chemical protection, wheat

Introduction
Frost causes major economic losses to the Australian grains industry through crop yield reductions and grain quality downgrading. Estimated costs of direct losses attributed to frost are approximately $63M annually in wheat and barley. While indirect costs from losses caused by delayed sowing to avoid frost are almost up to $300M per year. Many factors in modern cropping systems have attributed to making them more prone to frost damage. These include factors such as minimum tillage, stubble retention and timeliness of seeding. These higher yield potential crops combined with increased incidence and severity of frosts (Zheng et al. 2015) has caused modern farming systems to be more susceptible to losses from frost when they occur.

Past agronomic research has identified that management practices can influence the canopy temperature causing changes in frost damage. Clay delving, removing stubble and land rolling have all shown varying levels of success in increasing canopy temperature (Rebbeck et al. 2007). Practices such as clay delving are only suitable in specific soil types. Other practices used to manipulate the crop canopy have shown evidence to suggest frost damage may be reduced. These practices include, blending crop varieties, cross-sowing, increasing row spacing, lower seeding rate and delayed sowing (Rebbeck et al. 2007). Another agronomic approach to investigate in frost risk management is the use of chemical frost protectants. A number of commercially available chemical spray-on products are currently marketed to provide frost protection for various crops, mainly focusing on horticultural crops such as grapevines, tomatoes and fruit trees. Such products include anti-transpirants, biochemical compounds and plant growth regulators. The purpose of this this study was to evaluate the effectiveness of these products to mitigate frost severity in wheat.

Methods
A field experiment was undertaken at Mintaro, South Australia during 2014 to investigate the use of various chemical frost/cold stress protectants in their ability to alleviate frost damage symptoms in wheat. Wheat (cv. Mace and Scout) was sown at an appropriate seeding rate based on seed weight to reach a target density of 200 plants/m^2. Plots were 5m by 1.4m and sown using knife point and press wheels with 23cm row

spacing. There were 20 chemical treatments including an untreated control applied to each wheat variety. This included five different chemical products applied at various different crop growth stages (Table 1). Each chemical was applied using a hand-held, gas pressurized boom with a water volume rate of 100L/ha. Each treatment was replicated three times in a completely randomized block design. The experiment was sown seven times at weekly intervals beginning on the 15th of April. The purpose of this was to increase the duration of the wheat flowering window to increase the likelihood of a frost event occurring during this period of susceptibility.

Table 1. List of chemical treatments applied at various rates and application times.

Treatment No.	Treatment	Timing (Zadok growth stage)	Product rate (g.a.i/ha)
1	Control		
2	Dicarboxylic acids	Z32	20
3	Dicarboxylic acids	Z51/55	20
4	Dicarboxylic acids	Z61/65	20
5	Dicarboxylic acids	Z32 + Z51/55	20 + 20
6	Terpene polymer blend	Z32	275
7	Terpene polymer blend	Z51/55	275
8	Terpene polymer blend	Z61/65	275
9	Terpene polymer blend	Z32 + Z51/55	275 + 275
10	Di-1-p-menthene	Z32	2260
11	Di-1-p-menthene	Z51/55	2260
12	Di-1-p-menthene	Z61/65	2260
13	Di-1-p-menthene	Z32 + Z51/55	2260 + 2260
14	Experimental biochemical product	Z32	125
15	Experimental biochemical product	Z51/55	125
16	Experimental biochemical product	Z61/65	125
17	Experimental biochemical product	Z32 + Z51/55	125
18	Trinexapac-ethyl	Z30	100
19	Trinexapac-ethyl	Z33	100
20	Trinexapac-ethyl	Z39	100

Climate data was recorded at the experiment location, with the temperature measured at canopy height to identify the severity of the frost events. Crop growth stages were scored at weekly intervals from late stem elongation. Prior to maturity samples comprising of 30 heads were collected from each plot and all outer florets of each head were counted and identified as sterile or fertile. From this observation the percentage of sterile florets or frost induced sterility (FIS) was calculated for each head sample. At maturity, plots were harvested with a small plot harvester to determine grain yield.

All statistical analyses were completed using the GENSTAT statistical analysis software, using REML multiple experiment. Each sowing time was treated as a separate experiment and only those sowing times where frost events occurred during flowering or early grain fill were included in the analysis.

Results

The experiment location was affected by a large number of frost events during the 2014 growing season. In the months from August to October, there were 35 days with minimum temperatures below 0°C at Stevenson screen height (1.2m above ground level). The lowest temperature recorded was -5.7°C. The first two sowing times were removed from the analysis due to severe stem frost damage before many of the chemical treatments were applied.

Of the chemical products applied, none provided any significant gains in frost tolerance. Untreated control wheat plots averaged 42% floret sterility (Figure 1). The chemical protectants were not found to have any significant effect on sterility at any of the application times used in this study. Anti-transpirants, such as di-1-p-menthene and terpene treatments were included in the study as they may provide a physical barrier to reduce freezing damage to the plant. This study showed that they provided no useful effect to reduce the degree of frost damage in wheat. Similarly, the dicarboxylic acid product had no impact on grain sterility caused by frost. The plant growth regulator (PGR), Trinexapac-ethyl significantly increased the levels of floret sterility at all application times. The level of damage was consistently 50-51% sterility with applications ranging from early stem elongation (Zadoks 30) to flag leaf emergence (Zadoks 39). It is unclear why this increased level of sterility occurred. The PGR treatments delayed maturity by 1-3 days depending on sowing time, but due to the frequent nature of the frost events during the flowering period this small change in flowering time is unlikely to have influenced the level of frost damage. Differences in plant biomass were also negligible (data not shown), especially at the later sowing times. Trinexapac-ethyl may have affected the level of water soluble carbohydrates within the wheat plant, which may have influenced the level of frost sensitivity.

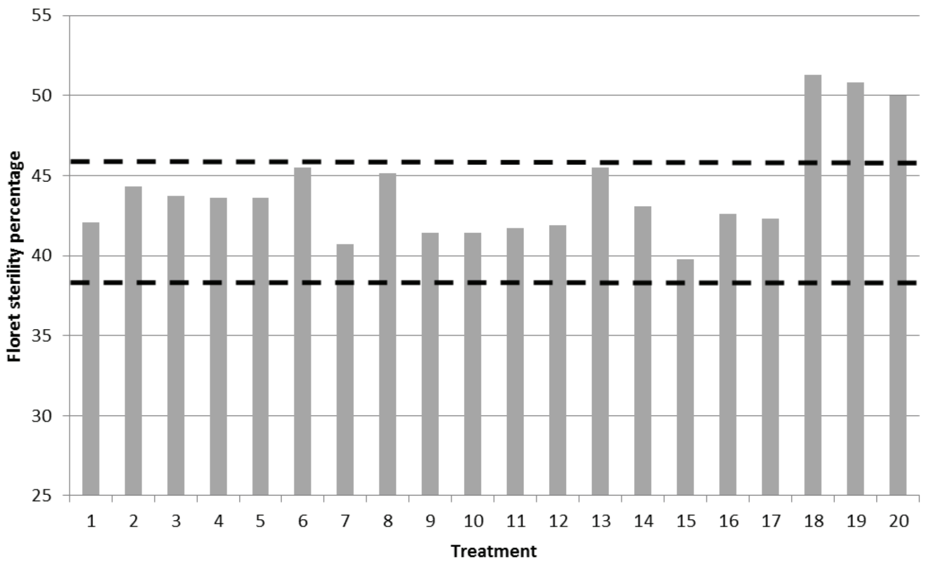

Figure 1. Effect of different chemical protectant treatments (Table 1) on floret sterility following frost events during reproductive development in wheat. Dashed lines represent significant difference to control (treatment 1) at *P*<0.05 level of significance (LSD = 3%).

The differences in grain yield were strongly correlated to the observed floret sterility from each of the chemical treatments. None of the tested chemical protectants provided any improvements in grain yield as was found with floret sterility. Untreated control wheat plots yielded on average 3027 kg/ha. Some protectant products trended to have slightly higher yields, but were not significantly different to the control (Figure 2). This result may have been influenced by the multiple severe frost events encountered during the season, where the extreme minimum temperatures and long duration below 0°C was too severe to enable the applied products to provide any benefit. The negative impact of the PGR, Trinexapac-ethyl on increased floret sterility was also reflected in grain yield. The 3-node (Zadoks 33) and flag leaf emergence (Zadoks 39) applications were significantly less that the control, with up to 8% lower grain yields (Figure 2).

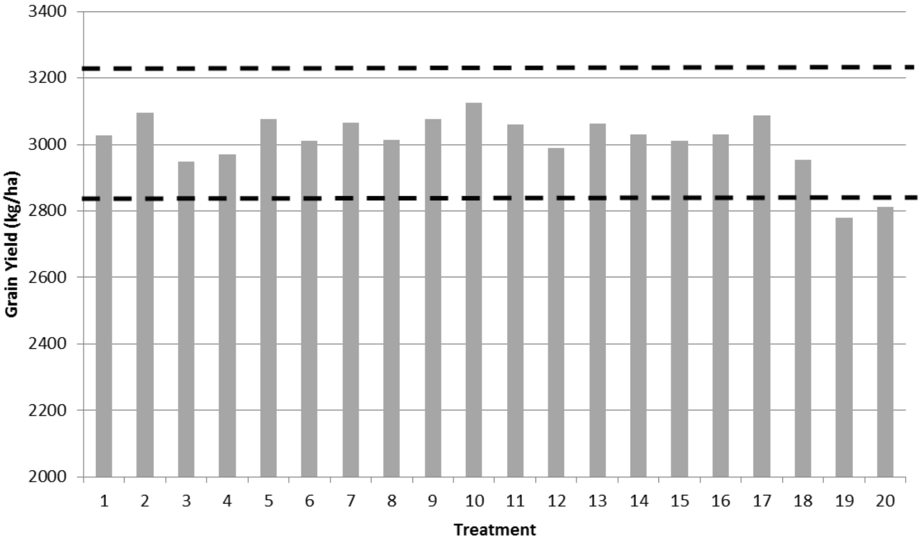

Figure 2. Effect of different chemical protectant treatments (Table 1) on grain yield following frost events during reproductive development in wheat. Dashed lines represent significant difference to control (treatment 1) at *P*<0.05 level of significance (LSD = 195kg/ha)

Conclusion

The ability of wheat to tolerate frost conditions was not improved by any of the products assessed in this study. The use of Trinexapac-ethyl increased the level of frost sensitivity, through higher floret sterility and consequently reduced grain yields. The reason for this change in frost susceptibility is unclear, but it is unlikely to be due to phenology changes that reduced exposure to frost. The severe frost conditions encountered during this study may have limited any potential effectiveness the chemical products may have provided. Therefore further evaluation of these chemical products is warranted. The increasing use of plant growth regulators to manage crop canopies makes further characterisation of the interaction with frost damage of significant interest.

References

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