Frost Mitigation Strategies for the UN

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Key Findings:

- This project aims to identify, and understand key risks associated with hot weather and frost effects on crops, to provide UN growers with more practical strategies to reduce yield losses from frost events.

- Frost risk significantly reduced yield in the Red Zone (high frost risk). Across all varieties, yields in the Red Zone were substantially lower than in the Green zone (low frost risk), with most varieties yielding 20–40% less. For example, Calibre wheat dropped from 1.04 t/ha (Green) to 0.71 t/ha (Red), highlighting the severe impact of frost exposure on flowering and grain set.

- Early sown, quick-maturing varieties performed best in both zones. Fast-maturing varieties like Vixen and Commodus performed consistently well across both zones when sown early. Vixen achieved 1.03 t/ha in Green and 0.79 t/ha in Red, suggesting that aligning flowering to avoid frost remains one of the most effective strategies for managing risk.

- Varietal response to frost was not always predictable. Some varieties showed unexpected performance under stress. Commodus barley, for example, yielded better in the frost-prone Red zone (0.69 t/ha) than in the Green (0.60 t/ha), indicating that localised microclimate or soil factors may influence outcomes more than maturity alone.

- Zoning trials provided critical insight into genotype and environment interactions. The dual-zone design clearly demonstrated that variety and management recommendations must be tailored to landscape position. A single sowing strategy across variable zones risks underperformance in one or both environments.

Background

Frost events have been a significant concern in the Upper North (UN) region of South Australia, resulting in substantial crop losses and economic impacts in past years leading up to 2024. The UN is susceptible to frost damage at various stages in the growing season, particularly during their critical reproductive stages, often leading to decreased yields. Consequently, depending solely on planting longer season varieties with later flowering times to evade frost risks is not always a dependable management strategy.

The 2024 season was particularly challenging, marked by severe frost events in September that compounded the effects of a dry winter and early spring. These conditions led to poor crop performance across many regions, with yield potential significantly limited. In response, many growers resorted to cutting severely frosted crops for hay as a salvage strategy. The total crop area harvested for grain was further reduced by the impact of frost, contributing to a revised grain production estimate of 5.2 million tonnes for 2024–25, which is 43% below the five-year average and the lowest total since 2008–09.

Given the UN's medium to low rainfall and heavy clay/clay loam soils, the region faces a high frost risk in August and the onset of summer heat and moisture stress from late September. These factors limit growers' ability to take advantage of early sowing opportunities to increase yields of main season wheat.

This project was developed based on findings from other key frost projects in South Australia (EPAG, Mid-North High Rainfall Zone). The aims were to identify and understand key risks associated with hot weather and frost effects on crops, as influenced by both agronomic and risk management strategies. It aims to provide UN growers with more practical strategies to reduce yield losses from frost events.

Aims

1. Evaluate the efficacy of various previously trialled frost management strategies (pre-frost and acute responses) in alleviating yield losses attributed to frost damage on a representative (or multiple), frost-prone sites in the UN.
2. Enhance UN growers' understanding of the origins of frost damage within the region and equip them with effective strategies to reduce associated risks.
3. Consolidate proven research outcomes, and related information, and extend key messages in a practical, flexible and applied manner that is locally relevant to growers, environment and farming systems.

Methodology

A site in Jamestown (Image 1) was identified with a high 'Red Zone' and moderate 'Green Zone' frost risk within the same paddock. Research activities in both zones - the 'Red Zone', where frost events are common, and the 'Green Zone', which is typically frost-free. This dual-zone approach enables a thorough evaluation of treatments—both under frost conditions and in areas unaffected by frost—providing insight into their effectiveness and potential yield benefits across varying environments.

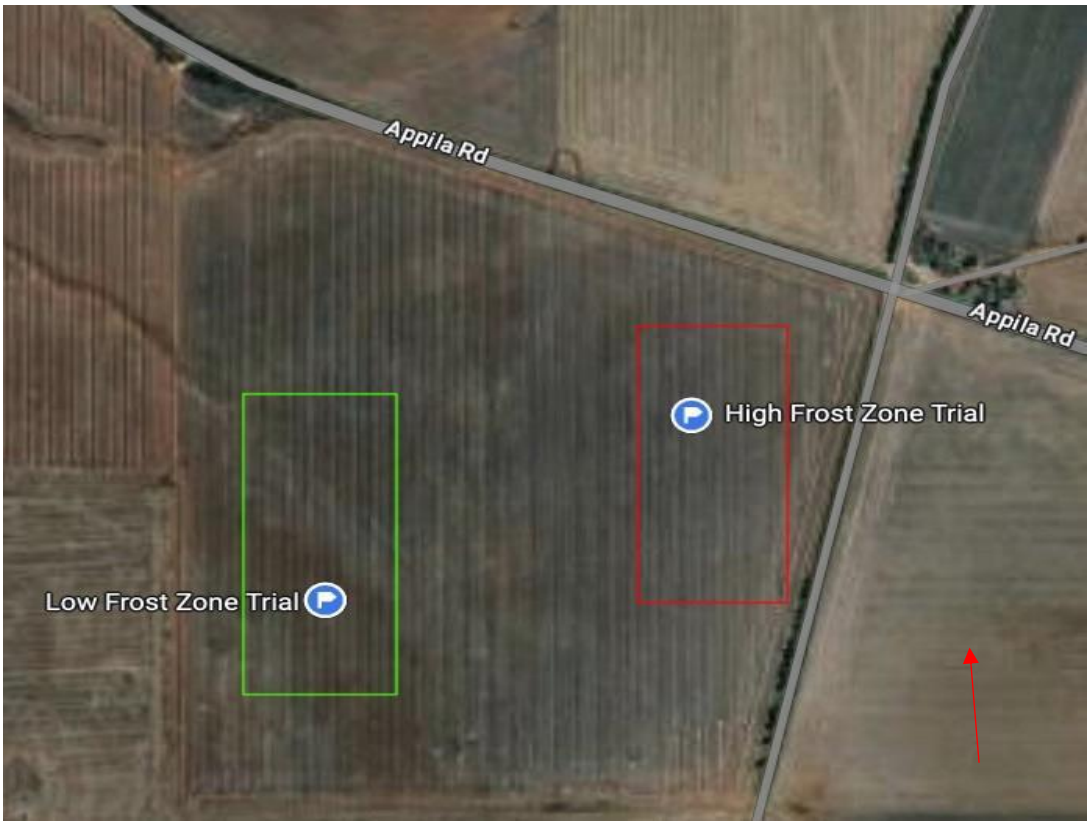

Image 1. High (Red) and Low (Green) frost risk Zone locations, within the paddock at Jamestown.

Stevenson screen temperature loggers (Ibuttons) were set up within each trial (Red Zone and Green Zone) at soil surface and canopy height.

Treatments were selected to assess the:

- Relative frost tolerance and yield stability of different varieties.
- Effectiveness of sowing date manipulation as a risk management strategy.
- Trade-offs between frost avoidance and other seasonal risks (e.g. terminal drought or heat).

To evaluate the interaction between genotype and environment in relation to frost risk, 9 wheat, 1 barley and 4 oat varieties with differing maturities were sown at two times of sowing (see below) in a split plot design, with three replicates. Plots were 12m long and 6 rows. Canola was included in the trial (non-statistical) due to its sensitivity to frost during early flowering, to provide a visual and physiological contrast for response to frost events.

Varieties sown early and in the main local sowing window:

- Oats – Kingbale, Archer, Bannister, Koala.
- Wheat – Bale, Mohawk, Denison, Bennett, Calibre, Rockstar, Dual, Vixen, LPB19-6850.
- Wheat mixture – Rockstar+Calibre+Vixen
- Wheat – Calibre: Frosted *vs* Late Fill
- Barley – Commodus.

Varieties sown early only:

- Barley – Commodus Frosted *vs* Late Fill; Commodus Frosted *vs* Mid Fill
- Canola – Hyola 970, Hyola Regiment, 45Y95CL

Plots were 12 m long, with 25 cm row spacing. **Sowing dates**: 1 May 2024 - early; 14 June 2024 - main local sowing window (post break of season). **Fertiliser at sowing**: Granuloc Z @ 100kg/ha cereals and 56kg/ha canola. **Fertilizer in-crop**: UAN (32% N) was applied in-crop on 10th July 2024: 135L/ha on cereals; 160L/ha on canola. **Pre-emergent herbicides:** cereals - 2.5L/ha Boxer Gold, 200ml Calisto, Roundup + Hammer knockdown; Canola - 1.2L/ha Overwatch. **Harvest** was on 4th December 2024.

Results

Frost events

Importantly, the heading/flowering phase at Zadoks GS 60–69 (particularly GS 65 – flowering, or anthesis), is particularly sensitive to frost damage in wheat, barley and oats. Vegetative phases (pre-GS 60) are much less sensitive to frosts.

Multiple frost events were recorded across the trial period, where minimum temperatures consistently fell below zero and distinct temperature patterns occurred amongst zones and treatments. Red Zone treatments (north and south) experienced the most severe frosts (Figure 1). These conditions likely impacted early vigour and crop development, although the relationship with final yield was less direct than expected and varied by variety and sowing time.

Early-season frost (28 July 2024): Minimum temperatures reached -6°C in the Red Canopy, with average temperatures below freezing across all Red Zone treatments. The Green Zone was milder, with an average of 0.23°C and a minimum of -3°C. At this stage, plants were in the less sensitive vegetative stages, and while this frost likely reduced vigour and early biomass, especially in the Red Zone, it did not coincide with sensitive reproductive phases and thus had limited direct yield impact.

Early–mid season frost (6 August 2024): The Red Zone again experienced significantly lower temperatures (minimums of -4.5°C) than the Green Zone (minimum -1.5°C). This event, observed across all TOS treatments, likely reinforced early-season stress (especially for earlier maturing lines such as barley and oats) but again occurred prior to flowering, limiting its direct effect on yield.

Late season frost (3 September 2024): A further frost event occurred with minimums down to -4.5°C in Red Zone South. Notably, the Red Zone (canopy height) remained colder (average 0.91°C) compared to the Green Zone (canopy height) (1.55°C), despite no sub-zero temperatures in the latter. By this date, early-

sown varieties such as Vixen, Calibre, Bannister, and Kingbale were at or near flowering (GS65) in both zones, making them highly susceptible to frost damage. This event coincided with critical reproductive stages for many wheats and oats in the Red Zone and may have contributed to lower grain set and yield.

Very late season frost (19 September 2024): A sharp frost event occurred late in the season, again showing the lowest minimums in the Red Zone (-6°C). The Green Zone and Red Zone recorded similar minimums (-3°C and -3.5°C, respectively), while the average temperature in Red Zone remained below zero (-1.045°C). Around this time, later-developing varieties such as Rockstar, Dual, and Kingbale (Late) were approaching or just entering flowering, placing them at heightened risk of frost damage during this sensitive stage. The impact of this frost likely varied with variety maturity and sowing time.

Overall, the Red Zone canopy treatments consistently experienced the coldest conditions, particularly on the southern side, indicating strong topographic or canopy-induced cold air pooling effects. These temperature differences highlight the importance of landscape position and canopy structure in influencing frost severity and potential yield impact.

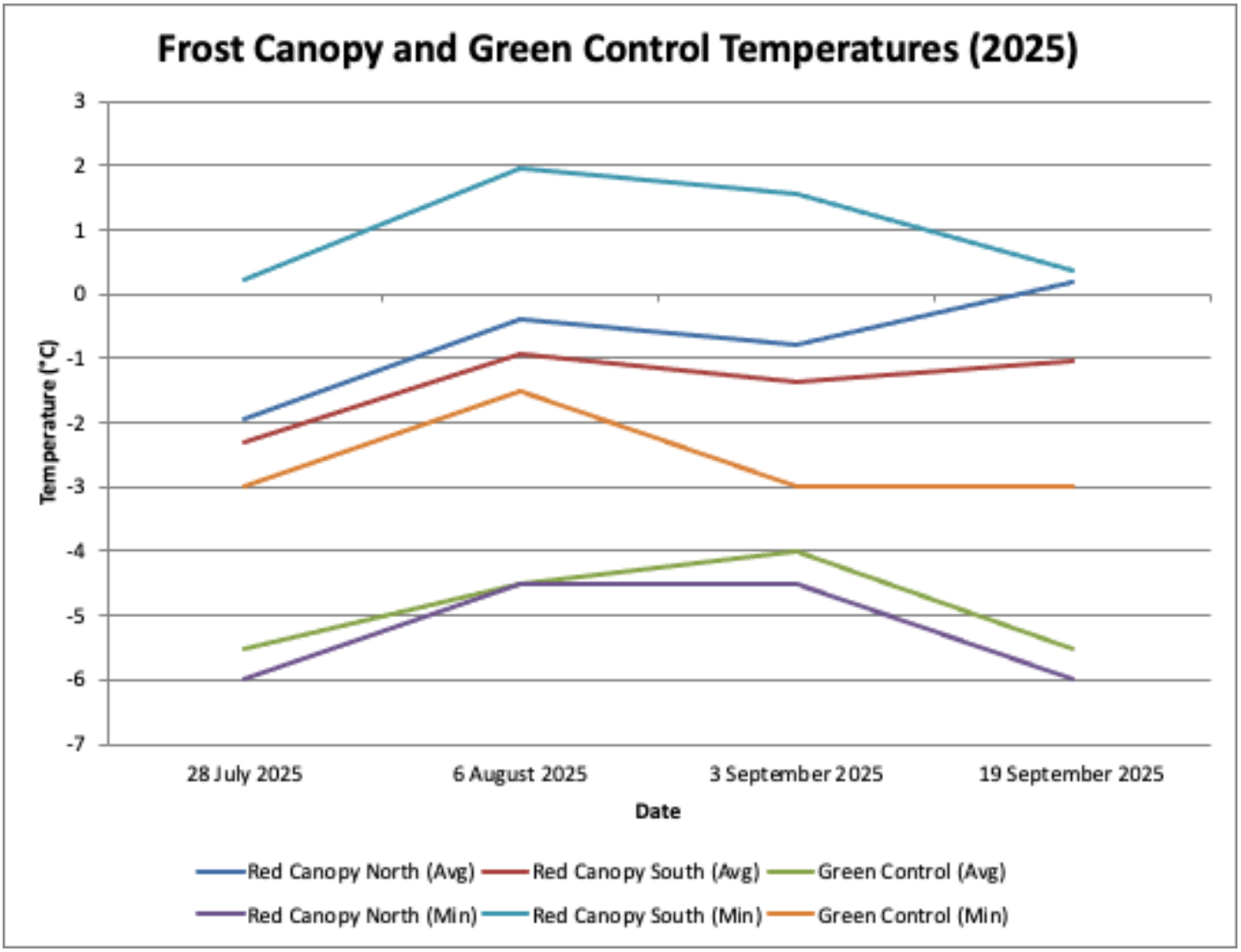

Figure 1. Canopy temperatures (average and min) during frost events in 2024 at Jamestown in the Red Zone in comparison to the Green Zone control.

Yield

The Green zone, characterised by more favourable soil conditions and reduced frost exposure, produced consistently higher yields across most varieties (Figures 4 & 6). Commodus barley yielded 0.47 t/ha, performing modestly despite its early maturity. High-yielding wheat varieties such as Calibre (1.14 t/ha) and Dual (0.91 t/ha) likely benefitted from flowering during frost-free periods and favourable spring moisture,

although no significant effect of time of sowing was detected. Bannister oats yielded 0.83 t/ha, reflecting strong adaptability under lower frost pressure. While later sowing generally showed a trend toward lower yields, varieties like Calibre (Late) still achieved 0.91 t/ha, demonstrating consistent performance across sowing times.

The Red zone (Figure 5) experienced lower overnight temperatures and a shorter effective growing season. Varieties such as Vixen and Calibre reached flowering (GS 65) in mid-September (18–19 Sept), coinciding closely with the late frost on 19 September, while later-flowering varieties including Rockstar, Kingbale, Dennison, and Dual entered flowering during early to mid-October, which was also a period marked by lingering cold conditions. Yields were notably reduced, particularly for crops that flowered during frost events. Although Calibre achieved the highest yield at 0.78 t/ha, followed by Dual (0.61 t/ha) and Rockstar (0.59 t/ha), the differences between these varieties were not statistically significant. Interestingly, Commodus barley outperformed its Green zone result, yielding 0.52 t/ha, suggesting a degree of frost or environmental tolerance. Kingbale oats maintained a yield of 0.59 t/ha, performing reasonably despite slower development under colder conditions. Later-sown varieties generally yielded below 0.60 t/ha, underscoring the risks associated with delayed maturity in frost-prone environments; however, the differences in yield among these varieties and sowing times were not statistically significant.

The most frost-tolerant crop in the 2024 trial — based on average yield in the frost-prone Red zone — was wheat, with an average yield of 0.70 t/ha across all wheat varieties. This was higher than oats at an average of 0.54 t/ha and barley at 0.52 t/ha. This suggests that, under the specific frost conditions at Jamestown, wheat exhibited greater resilience and yield stability than barley or oats. The most frost-tolerant cereal crop in Time of Sowing 1 (Early) was Vixen wheat, which recorded the highest grain yield in the frost-prone Red zone, achieving 0.95 t/ha. It also performed strongly in the Green zone, with 1.14 t/ha, indicating both frost resilience and high yield potential under unfavourable (drought) conditions.

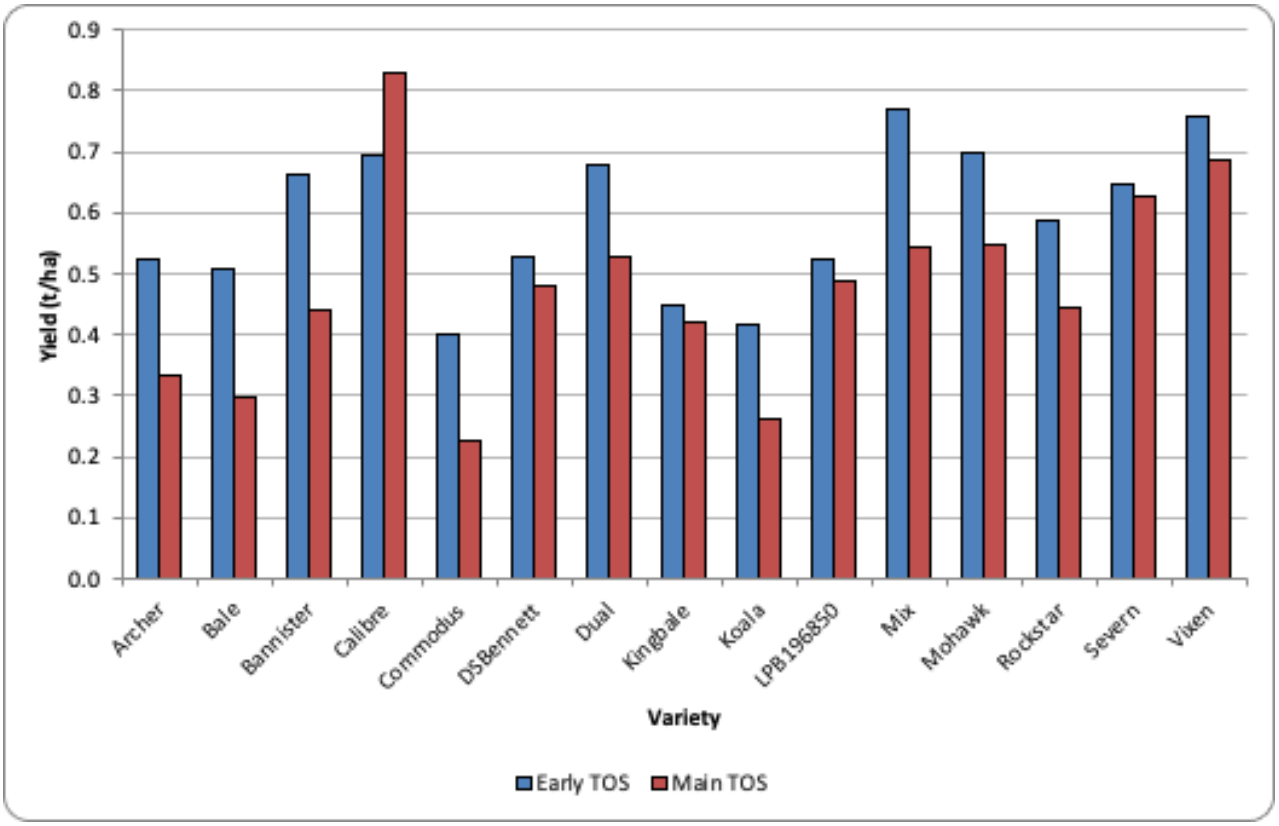

Figure 4. Yield (t/ha) at the frost trial in Jamestown for the Green Zone (low frost risk) showing Early time of sowing (blue) and Main time of sowing (red) for all varieties. Statistical comparison cannot be made as spatial modelling could not be completed for two different trial sites.

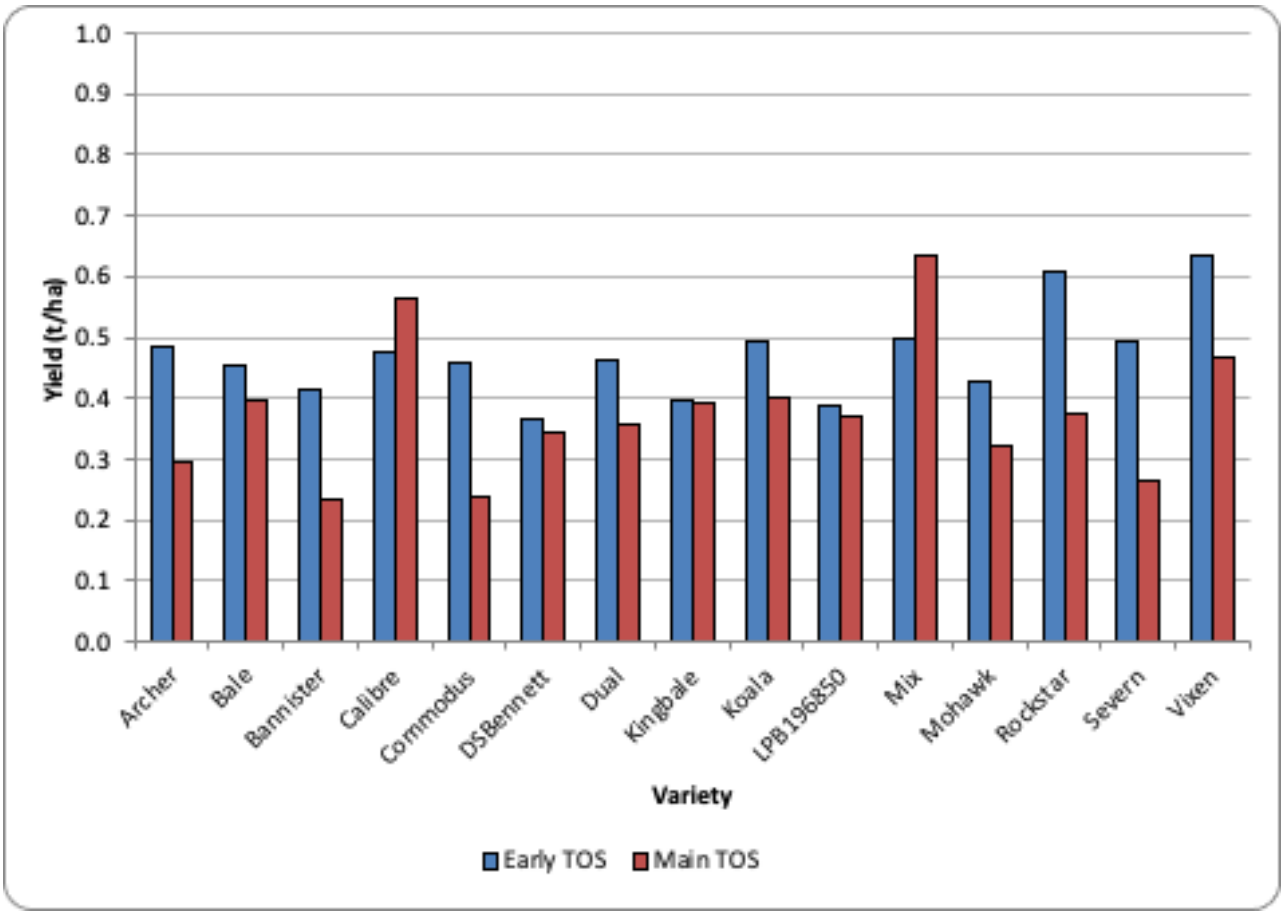

Figure 5. Yield (t/ha) at the frost trial in Jamestown for the Red Zone (high frost risk) showing Early time of sowing (blue) and Main time of sowing (red) for all varieties. Statistical comparison cannot be made as spatial modelling could not be completed for two different trial sites.

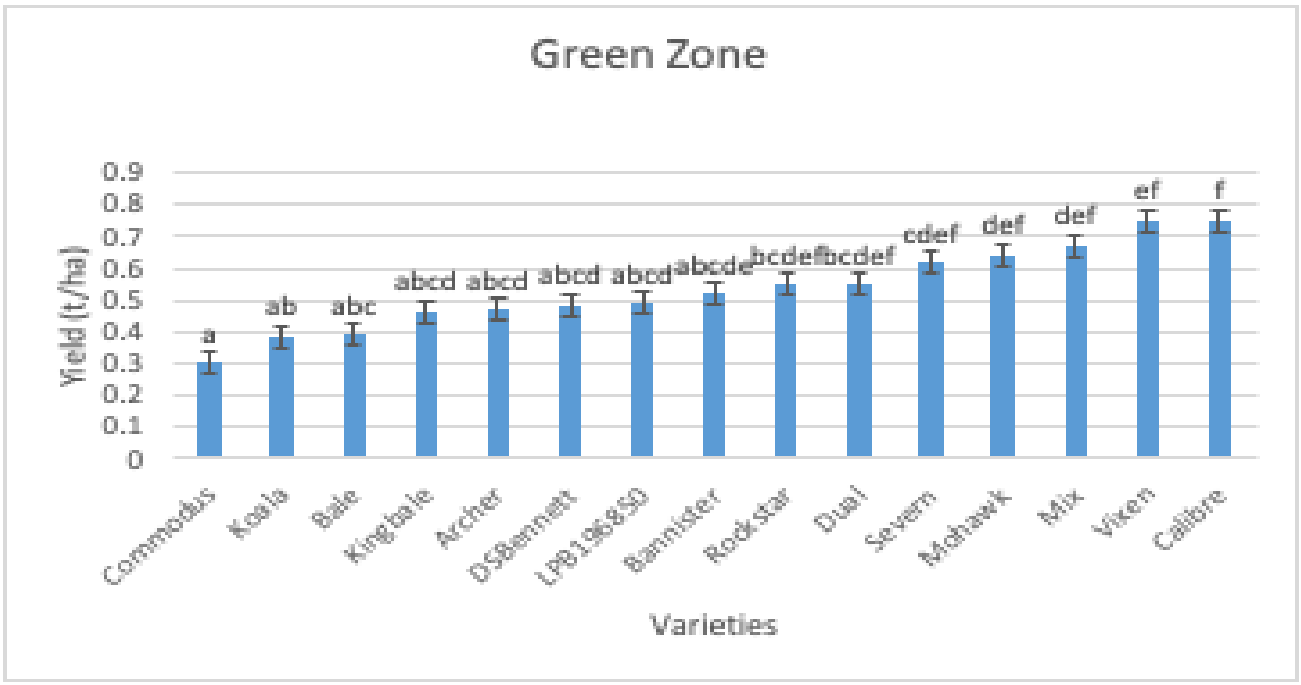

Figure 6. Yield (t/ha) of trial varieties in the Green Zone of the frost trial located at Jamestown, SA in 2024, with corresponding statistical letters above bars. Groups that share at least one letter are not significantly different from each other ($p < 0.05$). Groups with different letters are significantly different.

Takeaways for growers

The 2024 frost trial at Jamestown was the first year of a three-year project aimed at understanding and managing frost risk in the UN. Despite being an exceptionally challenging season—characterised by dry conditions and multiple frost events—the results have already provided valuable early insights. While these findings represent just one year of data, several clear strategies have emerged that may help growers begin to refine their approach to managing frost-prone paddocks. Ongoing trial work in 2025 and 2026 will continue to build on these observations and validate recommendations across seasons.

Know your frost zones - Variability in yield and canopy temperatures across the paddock confirmed that landscape position strongly influences frost risk. Identify high-risk (Red zone) areas using historical yield maps, topography, or local observations, and manage them differently to low-risk (Green zone) areas.

Select fast-maturing, frost-resilient varieties for early sowing - Varieties like Vixen and Calibre performed well when sown early, achieving higher yields and avoiding peak frost windows. Early sowing of quick-maturing types remains one of the most effective tools for reducing frost damage in high-risk areas.

Don't assume all crops will respond the same - Variety performance under frost was not always predictable. Commodus barley, for example, yielded better in the Red zone than in the Green. Trial results emphasise the need to validate varietal performance under local frost conditions.

Match flowering time to frost risk - Growth stage data showed that early-sown crops in the Green zone reached flowering (GS65) well before severe frost events, while later-sown crops in the Red zone flowered into riskier periods. Use sowing dates and maturity type to shift flowering away from known frost windows.

Consider whole-farm crop sequencing - Including canola in the trial highlighted the different frost sensitivities between crops. Strategically spreading flowering windows across crop types (e.g. early oats, mid wheat, late canola) can reduce the risk of whole-farm damage in frost years.

Use dual-purpose varieties in high-risk areas

Dual-purpose cereals that offer both high biomass and grain potential (e.g. certain oats, barley, or wheats) can provide a safety net in frost-prone zones. If frost severely impacts grain production, these crops can be cut for hay, offering a viable plan B without total crop loss. This strategy is particularly useful in early-sown paddocks with higher frost exposure.

Use in-season tactics where needed - In severe frost years like 2024, having a plan to switch damaged crops to hay or reduce input costs can help salvage returns and reduce losses.

These efforts underscore the importance of developing integrated frost management strategies that combine long-term approaches, such as soil amelioration and crop selection, with in-season tactics like hay cutting. By focusing on high-risk areas and implementing appropriate strategies, growers can optimise profitability while minimising losses due to frost.

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