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Project Code	
Project Type	

FINAL REPORT 2024

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PROJECT TITLE	
Agronomy strategies for frost management in pulse crops	

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PROJECT REPORT:

Executive Summary

Frost continues to be a major abiotic stress in Southern Australian cropping systems limiting the diversity of pulse crops adopted in high frost risk environments. The novel technique of frost mitigation using intercropping was explored in SAGIT funded research experiments conducted from 2021 to 2023 at Farrell Flat in the Mid North of South Australia (SA). The experiments involved sowing mixtures of two or three species in a single-skip row arrangement. In each treatment, lentil was present in a row on its own or with either one or two physically taller crop species (canola, faba bean, barley) in the alternate row. The mixtures were then compared to growing each of the components as monoculture crops. To determine the frost protection potential for the taller intercrop species to protect the shorter lentil plants, lentil pods were assessed each year following a reproductive frost event to determine differences in the frost damage to the developing lentil pods. The percentage of frost damaged pods was greater in treatments with more open canopy structure, such as lentil-barley, than three-species intercrops and lentil + faba bean when good crop establishment was achieved. A second trial involved testing two times of sowing (TOS) with 3-6 varieties of chickpeas and beans. This experiment showed visually the difference in grain quality obtained across the two TOS in June and July with less frost damage in the later sown crop. It also demonstrated an increase in shoot biomass from the TOS1 in June compared to TOS2 in July across both chickpeas and beans and an increase in grain yield in beans only in TOS1 compared to TOS2. Collectively, these results demonstrate the potential for intercropping as a management strategy in this frost prone environment.

Project objectives

This project will provide management strategies for growers to successfully include a wider range of break crops in frost prone environments.

The objective of this project was to develop and extend agronomy strategies for frost management to increase the overall productivity (both grain and forage), reduce seasonal risk factors, and focus on the incorporation of a range of break crop options into the farming system.

The expected outcomes include:

1. To increase the knowledge of mixed cropping systems, including how to adapt from a monoculture system to mixed species system.
2. To increase productivity and improve profitability through reduced input costs and increased productivity, while improving soil health, through the adoption of mixed species cropping and delayed sowing strategies in pulse crops.

Overall Performance

The project was successfully delivered to achieve the KPI's of the project. Field trials were conducted across multiple seasons from 2021-2023 and outcomes were presented to growers through field days at the sites including the Mid North High Rainfall Zone (MNHRZ) Spring Crop Walk and Frost Learning Centre Field Day by Penny Roberts and Dylan Bruce with Mick Faulkner.

List of personnel

- Dr Penny Roberts (formerly SARDI and now MSF)
- Mr Dylan Bruce (SARDI)
- SARDI Clare Agronomy field and lab teams
- Grower cooperator at Farrell Flat
- MNHRZ Group involvement for field days

The difficulty encountered was the lentil and canola intercropping mixes being difficult to separate out the grain of the two crop types in the intercropping mixes even due to similar size of seed. The grain quality testing was not successful due to not being able to separate crop types within the intercropping mixes.

KEY PERFORMANCE INDICATORS (KPI)		
KPI	**Achieved**	**If not achieved, please state reason.**
Trials designed and sown	Yes ☒ No ☐	
Trials managed and harvested. One field day hosted at site	Yes ☒ No ☐	
Progress report, summary of trial outcomes for 2021 season. Details of trials for 2022	Yes ☒ No ☐	
Trials managed and harvested. One field day hosted at site.	Yes ☒ No ☐	
Final report	Yes ☒ No ☐	

TECHNICAL INFORMATION

Aim 1: To increase the knowledge of mixed cropping systems, including how to adapt from a monoculture system to mixed species system.

A site was located at Farrell Flat with field trials conducted in 2021-2023 (2021: -33.851669°, 138.763248°, 2022: -33.865952°, 138.779948°, 2023: -33.902213°, 138.777664°). The experimental design was a randomised block with 3 replicates per treatment. Trials were sown with an 8-row experimental seeder, sowing dates were 20th May 2021, 14th June 2022, and 16th June 2023. Treatments included two and three species intercrops and the monoculture components of all species. Intercrop treatments were lentil + barley, lentil + canola, lentil + canola (canola removed), lentil + faba bean, lentil + faba bean + barley, lentil + faba bean + canola. Monoculture treatments were lentil, barley, canola, faba bean. Intercrops were sown in single skip row arrangement. In all intercrop treatments, lentil was sown in a row on its own with the other crop(s) sown in the alternate row. In three-species intercrops, canola and barley or canola and bean was sown in the alternate row together. All treatments were sown with the same fertiliser rate of 80 kg/ha of MAP, with sole canola and barley treatment receiving in-crop urea applications in line with district practice. All other in-crop management was the same for all treatments. The lentil-canola (canola removed) treatment had the canola component physically removed to reduce late season crop competition through physical removal of the canola canopy above the height of the lentil crop in Spring. This was undertaken on 30th Sept 2021, 19th Oct 2022 and 28th Sept 2023. Biomass cuts (4 rows by 1 m) at peak biomass.

Figure 1: Image of the field trial at Farrell Flat in 2023 showing the sole and mixed plots and tiny tags installed for canopy temperature readings.

Frost damage was assessed within 1 week of a reproductive frost event that caused physical damage to the lentil pods. Five randomly selected lentil plants were assessed per treatment. Each pod was visually assessed as non-frosted, frosted and viable, or frosted and non-viable. Temperate data was collected at site with an automatic weather station logging at 15-minute intervals. GenStat Version 24 (Release 2024 VSN International Ltd Hetfordshire UK) was used to analyse the dataset as a linear mixed model (REML) with year and treatment as the fixed effect and replication as the random effect. Levels of probability greater than 0.05 (P>0.05) were considered non-significant, and standard errors (se) least significant differences (l.s.d.) were calculated to compare treatment means when P-values were less than 0.05.

The number and severity of frost events differed between years (Table 1), as did the level of lentil pod damage (P<0.001). In 2021, two consecutive frost events occurred during the lentil podding growth stage on the 10th and 11th October that caused visible pod damage. The event on the 10th lasted for 7 hrs 45 mins, reaching a minimum of -3.6˚C, followed by 7 hrs of frost on the 11th that reached a minimum of -1.0˚C. In 2022, the site experienced a long-wet spring resulting in a low number of frost events, and no frost events resulted in visible pod damage. In 2023, a frost event occurred during the lentil podding growth stage on 25th October that caused visible pod damage. The event lasted for 8 hrs 15 mins, reaching a minimum of -3.7˚C.

Table 1. The number of frost events and total frost minutes (defined as temperatures recorded as 0˚C or below) for the months of August, September and October when the lentil crop was in the reproductive growth phase at Farrell Flat, 2021-2023.

Year	Month	No. Frost Events	Total Frost Minutes
2021	August	9	2340
	September	6	1275
	October	10	1995
	Total (Aug-Oct)	25	5610
2022	August	2	375
	September	4	930
	October	1	390
	Total (Aug-Oct)	7	1695
2023	August	7	2445
	September	2	525
	October	4	870
	Total (Aug-Oct)	13	3840

In 2021, favorable seasonal conditions allowed for greater biomass production, with high biomass across all crops (Figure 2). Faba bean established well in 2021 and developed a good canopy as indicated by biomass. Greater canopy biomass translated into higher levels of frost protection with lentil + faba bean + canola and lentil + faba bean intercrops recording the lowest levels of pod damage, 5 times less than monoculture lentil (Figure 3). This is likely driven by the faba bean component, with faba bean biomass the same in the two treatments and making up a greater proportion of the three-species intercrop in 2021. Further, pod damage in the lentil + canola intercrop was higher than monoculture lentil in this season, indicating the canola canopy did not offer frost protection in this season. Similarly, the canopy of barley offered no pod protection with pod damage higher in the lentil + barley intercrop than monoculture lentil.

In 2023, there was poor faba bean establishment resulting in low biomass production (Figure 2). Faba bean represented a small component of the lentil + faba bean + canola and lentil + faba bean intercrops and a greater amount of pod damage was recorded in 2023 compared to 2021 although still lower than monoculture lentil. This is likely driven by a poorer faba bean canopy offering lower levels of frost protection (Figure 3). In this year, canola made up a greater proportion of the lentil + faba bean + canola treatment affording twice the level of frost protection compared to the monoculture lentil, with pod damage lower than the lentil + faba bean intercrop and equal to that of the lentil + canola intercrop, with biomass of the canola the same across the intercrops containing canola. As with the 2021 season, the lentil + barley intercrop had higher pod damage than the monoculture lentil. These results indicate the architecture of the companion species is important in determining the level of frost protection it provides.

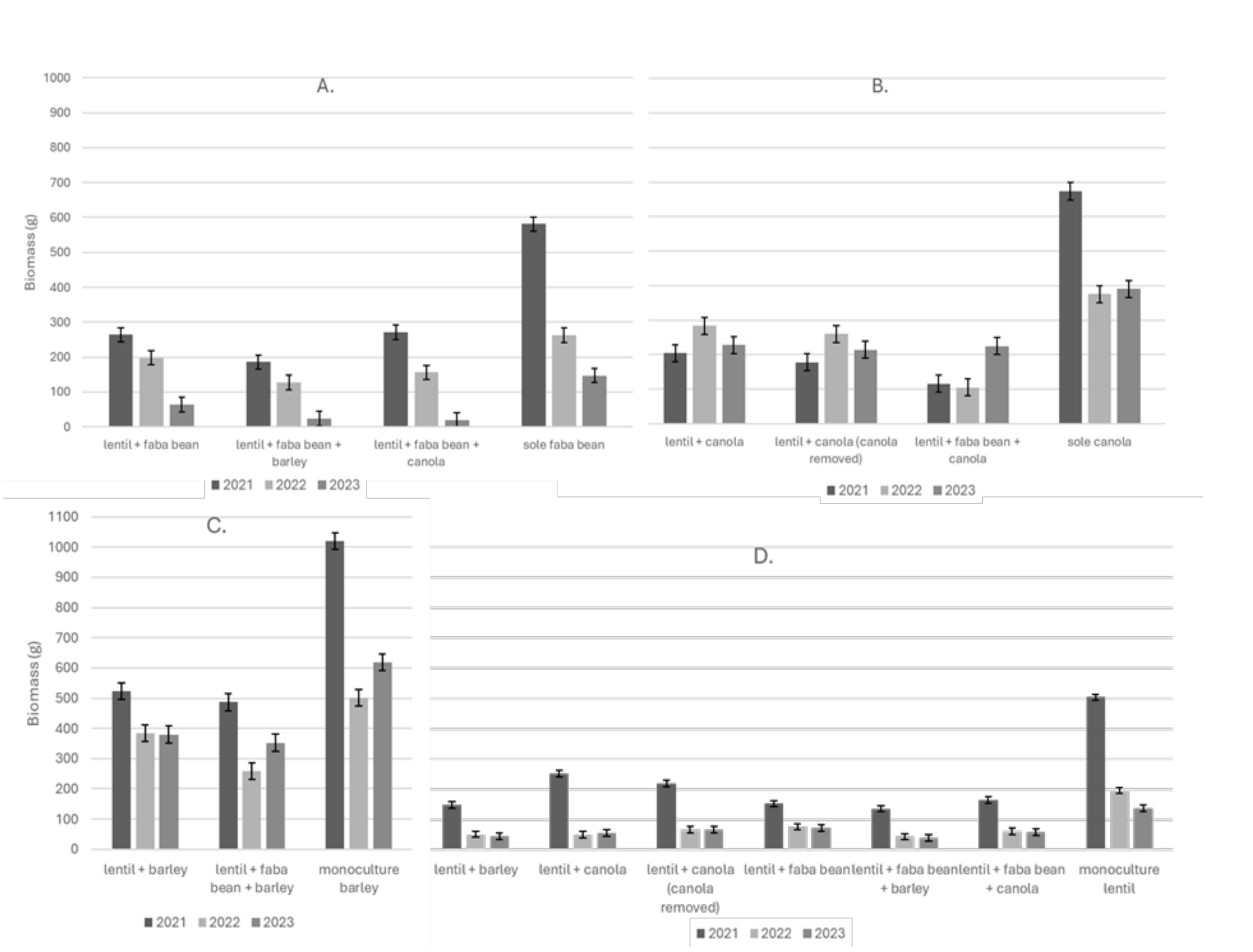

Figure 2: Variation in biomass measured at crop maturity of A. faba bean, B. canola, C. barley and D. lentil grown in intercrop and monoculture at Farrell Flat, 2021-2023. Error bars represent the standard error at p=0.05.

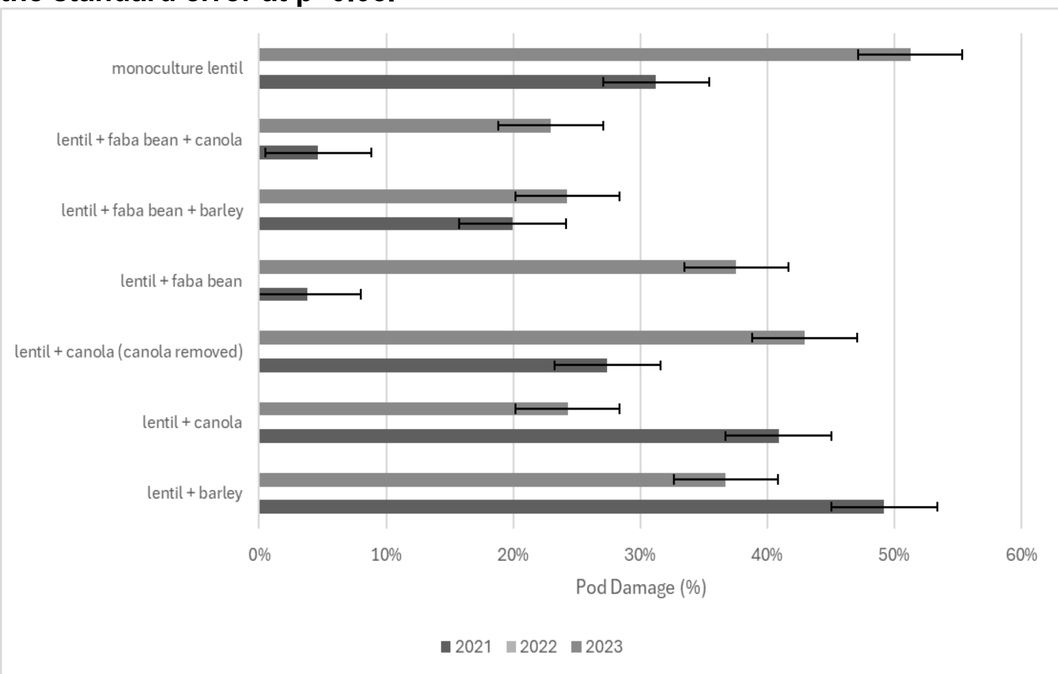

Figure 3: Percentage of lentil pod damage measured post reproductive frost event causing viable pod damage at Farrell Flat in 2021 and 2023, no frost events caused visible pod damage in 2022. Error bars represent the standard error at p=0.05.

Grain quality was difficult to obtain from the intercropping mixes. The following mixes have been tested including all the sole crops, the barley +lentil + beans and the lentil + barley. However, the lentil + canola has not been able to be separated even after subsequent sieve due to the similar seed size and fragments of lentils in the canola grain (Figure 4)

Figure 4: The lentil and canola intercropping mix after sieving showing the difficulty in separating out the grain of these two crop types for grain quality analysis due to similar size of seed.

Aim 2. To increase productivity and improve profitability through reduced input costs and increased productivity, while improving soil health, through the adoption of mixed species cropping and delayed sowing strategies in pulse crops.

1. 2 times of sowing: in June (14th 2022, 16th 2023) and late winter sowing (26th July 2022, 31st July 2023)
2. 2 species: chickpea and beans
3. 3-6 varieties of each species: 3 bean (faba bean, broad bean and narbon bean (2022 only)) and 6 chickpea varieties (Southern, Northern and chill tolerant lines).

The first time of sowing occurred on the 14th June 2022 and 16th of June 2023 and the second time of sowing was the 26th July 2022 and 31st July 2023 (Fig. 5). The experiments were a split-plot design with crop species and time of sowing randomly assigned to the whole plot and variety to the sub plot.

Figure 5: Time of sowing trial at Farrell Flat in 2023 showing the TOS 1 (June) and TOS2 (July) for the two crop species – beans and chickpeas.

The results of the shoot biomass (t/ha) across TOS1 (June) and TOS2 (July) from 2022 indicated that the earlier TOS generated higher biomass than the later TOS in the bean crop types and PBA Royal (Figure 6 a). Chill 1, Chill2 and PBA Pistol chickpeas generated their higher biomass when sown later in July, favoring the softer finish to the season. Results from 2023 indicated that development of higher biomass was favored by sowing earlier in June, except for the PBA Striker and PBA Royal variety (Figure 6 b). The grain yield (t/ha) results from 2022 favored earlier sowing for the bean crop types, except Narbon, while chickpea achieved either similar yield, or increased yield from a delay in sowing till late July, except PBA Royal (Figure 6 c). The yield response of chickpea in 2022 showcases the crop types ability to tolerate higher temperatures during reproductive development, when adequate soil moisture is available. The grain yield results from 2023 indicated that only the beans showed an increase in grain yield from the earlier TOS1 compared to the later TOS2 sowing, due to the tighter finish and lack of soil moisture available later in the season of 2023 (Figure 6 d).

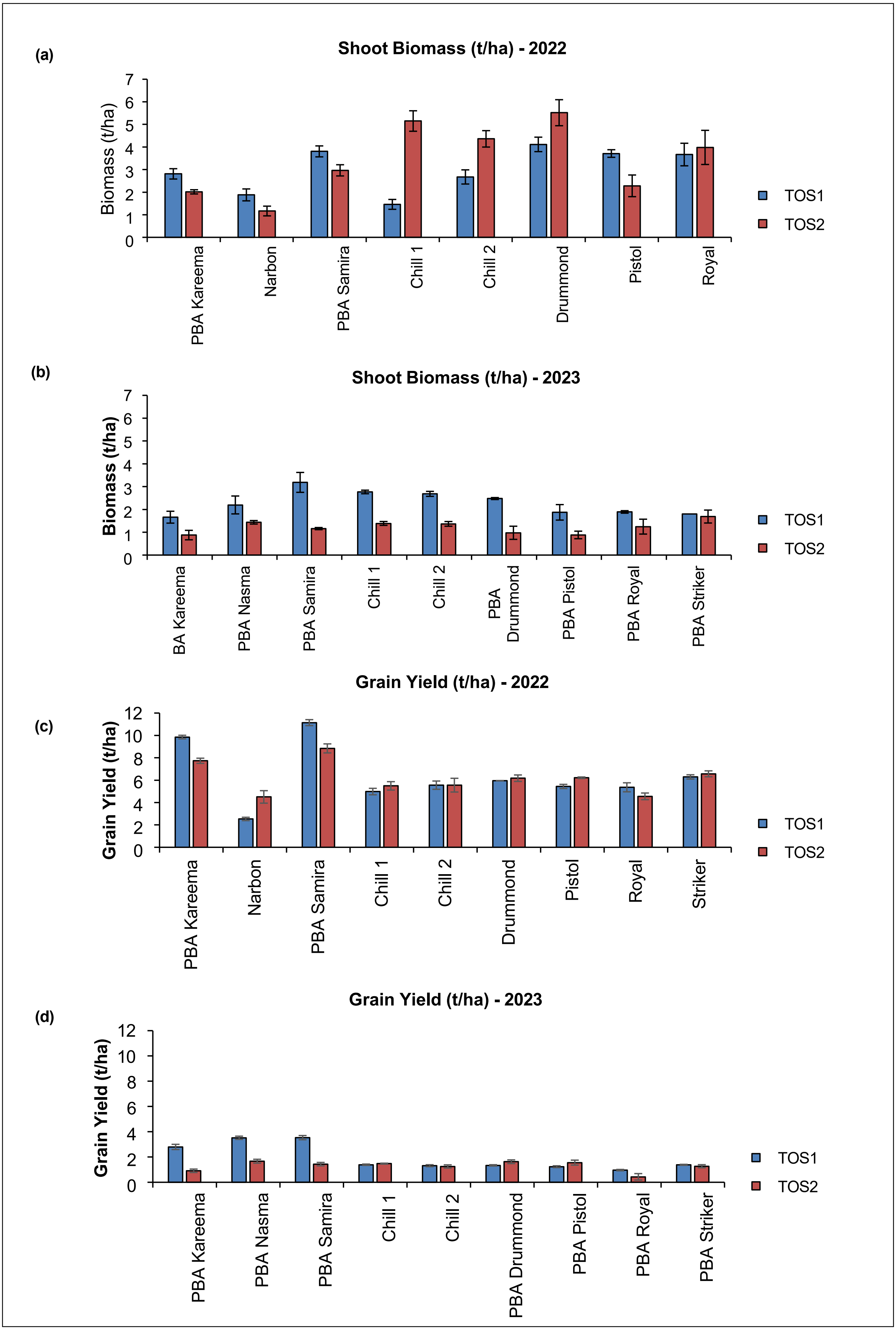
(a)
Shoot Biomass (t/ha) - 2022
Biomass (t/ha)
0
1
2
3
4
5
6
7
PBA Kareema
Narbon
PBA Samira
Chill 1
Chill 2
Drummond
Pistol
Royal
TOS1
TOS2
(b)
Shoot Biomass (t/ha) - 2023
Biomass (t/ha)
0
1
2
3
4
5
6
7
BA Kareema
PBA Nasma
PBA Samira
Chill 1
Chill 2
PBA Drummond
PBA Pistol
PBA Royal
PBA Striker
TOS1
TOS2
Grain Yield (t/ha) - 2022
(c)
Grain Yield (t/ha)
0
2
4
6
8
10
12
PBA Kareema
Narbon
PBA Samira
Chill 1
Chill 2
Drummond
Pistol
Royal
Striker
TOS1
TOS2
Grain Yield (t/ha) - 2023
(d)
Grain Yield (t/ha)
0
2
4
6
8
10
12
PBA Kareema
PBA Nasma
PBA Samira
Chill 1
Chill 2
PBA Drummond
PBA Pistol
PBA Royal
PBA Striker
TOS1
TOS2

Figure 6: The shoot biomass (t/ha) in (a) 2022 and (b) 2023 and grain yield (t/ha) in (c) 2022 and (d) 2023 for TOS1 (blue) and TOS2 (red) for the beans (PBA Kareema, Narbon (2022), PBA Nasma (2023) and PBA Samira) and the chickpea (Chill1, Chill 2, PBA Drummond, PBA Pistol, PBA Royal and PBA Striker) varieties. Values are presented as the mean (*n* = 3) ± SEM, except PBA Royal and PBA Striker in TOS2 of 2023 which had *n*=2 due to grain harvesting error.

There were visual differences in grain quality obtained with the later sown chickpea lines showing less frost damage compared to the earlier sown lines (Figure 7).

Figure 7: The visual difference in grain quality obtained from chickpea varieties tested in the two TOS in June and July 2023 showing the frost damage among varieties and less damage in the later sown crop.

The information in this report for Aim 1 was prepared by Dr Penny Roberts and Mr Dylan Bruce for a proceeding paper for the Australian Agronomy conference.

CONCLUSIONS REACHED &/OR DISCOVERIES MADE

This work demonstrated frost mitigation could be achieved in some years for a high value pulse crop, such as lentil, by manipulating the architecture of the overall plot by intercropping with a taller and bulker crop type, such as faba bean or canola. This study indicates the level of pod protection is likely driven by canopy architecture with barley providing no level of protection, canola some, and a well-established faba bean crop the highest level of protection. Three-species intercrops appear to offer a risk management strategy in the circumstance of poor crop establishment of one of the species, however when established well the two-species intercrop of lentil + faba bean were equally effective in reducing pod damage caused by reproductive frost from 31% to 4%. A second trial showed an increase in shoot biomass from a time of sowing in June compared to a second time of sowing in July across both chickpeas and beans and an increase in grain yield in beans only in TOS1 compared to TOS2. In summary, this project demonstrated a novel management strategy that can be employed to reduce the impact of reproductive frost on lentil grown in a high-risk frost environment.

INTELLECTUAL PROPERTY

None

APPLICATION / COMMUNICATION OF RESULTS

The main findings of the project included demonstrating that frost mitigation can be achieved in some years using intercropping of lentil with a taller crop, such as faba bean or canola. Pod protection appears to be linked to canopy architecture with barley providing no level of protection, canola some, and a well-established faba bean crop the highest level of protection. Three-species intercrops appear to offer a risk management strategy in the circumstance of poor crop establishment of one of the species, however when established well the two-species intercrop of lentil + faba bean were equally effective in reducing pod damage caused by reproductive frost from 31% to 4%. An earlier time of sowing in June compared to July resulted in greater biomass across both chickpeas and beans for most varieties and an increase in grain yield in beans only in TOS1 compared to TOS2.

Whilst there are farmers in Southern Australian who have adopted the practice of intercropping, it is important to acknowledge there are barriers to adoption for many broadacre farmers.

Field trials were presented at the MNHRZ Spring Crop Walk and Frost Learning Centre Field days including by Dr Penny Roberts, Mr Dylan Bruce and Mr Mick Faulkner. The site was well received by growers and advisors visiting the trials. There were also regular updates on the site provided by Dr Penny Roberts through her Twitter (X) account over the year. A proceeding paper outlining the results presented in this final report has been submitted to the Australian Agronomy conference to be held in Albany in October this year.

POSSIBLE FUTURE WORK

Further work is required to determine the optimum canopy structure for frost mitigation, and growers will also need to be supported through peer-to-peer learning and participatory research to achieve an increase the adoption of intercropping. Trials testing these results across different soil types is required to check the reliability in other environments for these intercropping mixes and time of sowing findings.