Evaluating the benefits of multi-species cropping; a four-year summary

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Key findings

- Pulse productivity and performance through intercropping practices at Hart, SA was decreased in most cases when compared to monocrop (sole crop) systems across a number of growing seasons from 2019 – 2022.
- Intercropping treatments at Hart in 2022 had land equivalent ratio (LER) values ranging from 0.81 – 1.07. This indicates that overall, grain yield was reduced when two crop species were grown together, compared to their sole crops. Canola + vetch (LER = 1.07) was the only intercropping treatment to achieve a land equivalent ratio (LER) greater than 1.
- The reason for lower LER values at Hart in 2022 compared to other studies in the region (Roberts et al. 2017) are not known, however, in addition to the soils and climate of a region, factors including row intercrop planting configurations and the compatibility of the cultivars grown can affect yield outcomes.
- Soil water dynamics, including infiltration and uptake, measured by soil moisture probes were similar for all intercrop and monocrop treatments across four years of trials. No residual effects were observed in subsequent year's crops.

Introduction

Intercropping is a system resulting in two or more species sown and harvested together (Parvin 2020). This method has been adopted by a small number of Australian growers and is generally utilised within dryland broadacre cropping systems. An intercropping system recognised as a suitable option for many years is canola and field pea, otherwise known as 'peaola' (Kirkegaard 2019). Potential benefits from these systems include reduced input costs, rotational benefits, and soil improvement (Fletcher 2020). Companion cropping is also a form of multi-species cropping where crops are sown together, however one species is terminated either by grazing or herbicide use (Fletcher 2020). This concept could provide complementary benefits to a 'cash crop' through improved nutrition by nitrogen fixation, soil structure or weed suppression (Kirkegaard 2019). Common companion cropping mixes are currently wheat sown as a mixed row (Figure 1) with a legume; vetch, faba bean or field pea.

The aim of this four-year trial series was to assess the feasibility of integrating multi-species crops through intercropping strategies in current winter rotations. Intercropping systems and their impact on subsequent years' cereal crops was investigated.

Methodology

Intercropping trials were split-plot designs with three replicates and six crop treatments in 2019 and twelve crop treatments from 2021 – 2022.

Pulse and oilseed intercropping and monocrop (sole crop) treatments trialed from 2019 – 2020;

1. Canola (Stingray TT)
2. Field pea (Wharton)
3. Chickpea (Genesis090)
4. Linseed (Croxton)
5. Peaola; canola + field pea
6. Chickpea + linseed

Pulse and oilseed intercropping and monocrop treatments trialed from 2021 – 2022;

1. Canola (HyTTec Trophy)
2. Field pea (Wharton)
3. Chickpea (Genesis090)
4. Faba bean (Bendoc)
5. Lentil (Hallmark XT)
6. Vetch (Timok)
7. Peaola
8. Chickpea + canola
9. Faba bean + canola
10. Lentil + canola
11. Vetch + canola
12. Faba bean + lentil

A standard knife-point press wheel plot seeder was modified and used to sow the monocrop and intercrop treatments 8 rows wide (Table 1 & 2). The intercrop plots were sown in a double skip arrangement resulting in two rows of each crop sown together (Figure 1). All plots were assessed for soil water, crop biomass at anthesis (t/ha), harvest index (HI), grain yield (t/ha), 1000 grain weight (g) and land equivalent ratio (LER).

Anthesis cuts were completed by sampling 4 rows x 1 m sections in two areas of the plot. All samples were oven dried at 60°C for 48 hours and weighed. At harvest, whole plot grain samples were retained. Grain yield for intercropping treatments was then calculated by separating seed with a sieve and weighing, to calculate individual crop yield.

Table 1. Seeding and harvest operations for intercropping trials at Hart from 2019 – 2020.

2019	**Plot size**	4.2 m x 36.0 m	**Crop type**	Pulse and oilseed
	Seeding date	May 28, 2019	**Fertiliser**	MAP (10:22) + 2% Zn @ 75 kg/ha
	Location	Hart, SA		Urea (46:0) @ 100 kg/ha (canola
	Harvest date	November 26, 2019		and peaola only) Aug 6
2020	**Plot size**	4.2 m x 36.0 m	**Crop type**	Cereal phase
	Seeding date	May 5, 2022	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
	Location	Hart, SA		July 2: Easy N (42.5:0) @ 80 L/ha
	Harvest date	December 14, 2020		
2020**	**Plot size**	2.2 m x 10.0 m	**Crop type**	Pulse and oilseed
	Seeding date	May 5, 2022	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
	Location	Hart, SA		Urea (46:0) @ 100 kg/ha (canola
	Harvest date	December 14, 2020		and peaola only)

***A complimentary trial was implemented to further assess monocrop and intercrop combinations.*

Table 2. Seeding and harvest operations for intercropping and cereal trials at Hart in 2022.

2021	**Plot size**	2.2 m x 10 m	**Crop type**	Pulse and oilseed
	Seeding date	June 10, 2021	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
	Location	Hart, SA		Urea (46:0) @ 50 kg/ha (sole canola and canola intercropping plots)
	Harvest date	N/A		
2022	**Plot size**	2.2 m x 10 m	**Crop type**	Cereal phase
	Seeding date	June 16, 2022	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
	Location	Hart, SA		July 22: Easy N (42.5:0) @ 70 L/ha
	Harvest date	December 14, 2022		August 17: Easy N (42.5:0) @ 60 L/ha
2022**	**Plot size**	2.2 m x 10 m	**Crop type**	Pulse and oilseed
	Seeding date	June 16, 2022	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
	Location	Hart, SA		Urea (46:0) @ 100 kg/ha (sole canola and canola intercropping plots)
	Harvest date	December 1, 2022		

***Yield and quality data could not be analysed from intercropping trials at Hart in 2021. This was due spring weather events causing significant crop damage prior to harvest. This trial was replicated in 2022.*

In 2019 and 2021, all trial plots were over-sown to Scepter wheat to assess carry over effects from previous monocrop and intercrop treatments on a subsequent year's cereal crop. All cereal plots were assessed for soil water, early crop vigour using NDVI (Normalised Difference Vegetation Index), grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (2.2 mm screen). All trials were managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

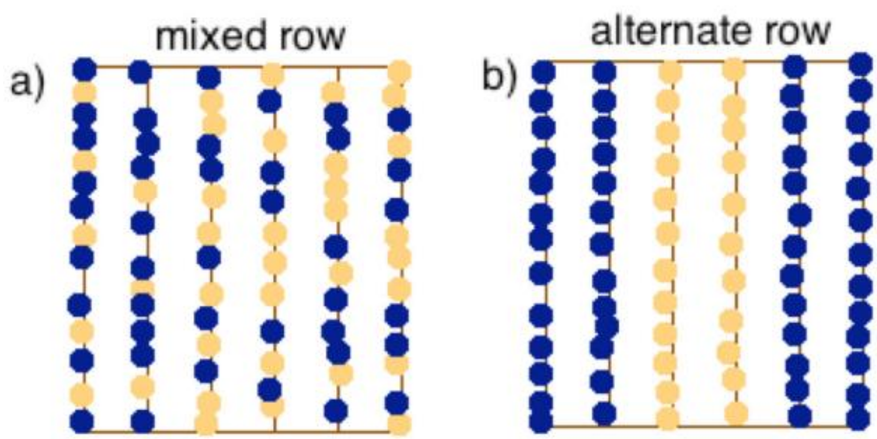


Figure 1. Sowing orientation of two crops (crop A = blue dot, crop B = orange dot) showing mixed row intercropping (left) and alternate row or 'double skip' row arrangement. Figure sourced from Roberts P, 2020.

Soil water assessments

Soil moisture probes were installed on June 5, 2019. The configuration of the capacitance probes was EnviroPro 80 cm EP100GL-08's and contained sensors at 10 cm intervals, starting at 15 cm through to 85 cm. A total of 15 moisture probes were installed in all treatments (excluding linseed monocrop) and replicates and soil moisture was monitored from June 2019 – November 2020. Moisture probes were again installed July 2021 and soil moisture measured until November 2022. A total of 18 moisture probes were installed for canola, field pea, chickpea, peaola, faba bean + canola and canola + chickpea plots.

Land equivalent ratio (LER)

Land equivalent ratio values were calculated to measure intercropping productivity relative to monocrop treatments. The LER is expressed as: LER = (intercrop yield A / sole yield A) + (intercrop yield B / sole yield B). An LER value of 1.0 means the productivity of the intercrop was equivalent to the monocrop. An LER value of > 1.0 means the intercropping treatments are more productive than the monocrop and is referred to as 'over-yielding' (Parvin 2020).

Results and discussion

Crop biomass

In 2019, NDVI was highest for linseed (followed by canola), indicating it had superior vigour and ground cover. Other treatments including chickpea + linseed and peaola produced similar canopy cover (Parvin 2020) but was lower than linseed. At pod fill, chickpea and linseed produced similar biomass to their intercrop, however sole field pea produced greater biomass when compared to the intercropping treatment. This is likely a result of canola having reduced biomass in dry growing season conditions. When crop biomass was measured at anthesis in 2022, all canola intercropped with a pulse produced similar biomass to the sole canola treatment, averaging 4.91 t/ha. Sole legume crops also provided greater biomass when compared to intercropping legume treatments (P value = <0.001).

Grain yield

The performance of intercrop and monocrop treatments at Hart from 2019 – 2022 were similar, even across varying seasonal conditions. In 2019, grain yields for monocrop and intercrop treatments were below average, resulting from decile 1 conditions (Figure 2). The LER for chickpea + linseed (0.79) and peaola (0.96) was < 1 (Parvin 2020), indicating a reduction in both grain yield and crop productivity for these systems under dry conditions (Figure 3). In 2020, peaola performed similarly with an LER of 0.96, however chickpea + linseed had a marginal increase, with an LER of 1.0. Overall, monocrop yields were higher in 2020, however similar results were observed between intercrops. This was initially understood to be a result of below average rainfall in winter months, contributing to an increase in crop competition for stored soil moisture (data not shown). However, results from 2022 indicate intercrop yields may be reduced, even under favourable conditions in the medium rainfall zone of the Mid-North.

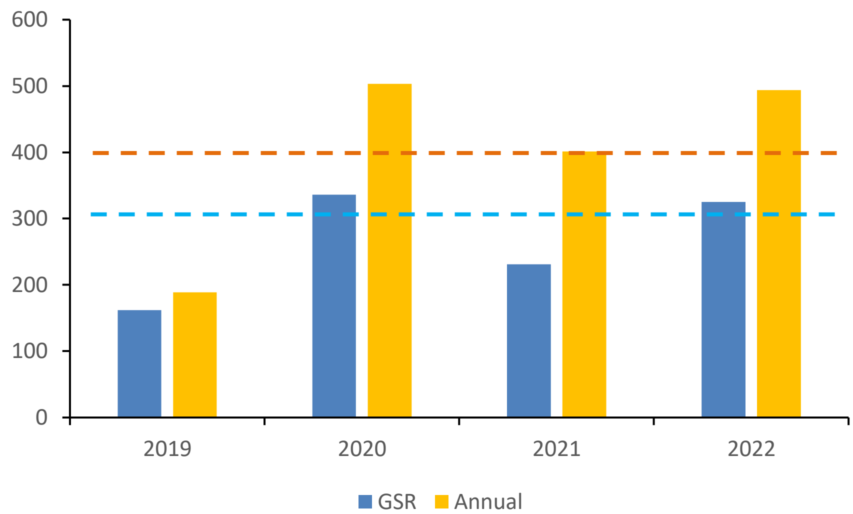


Figure 2. Average annual and growing season rainfall (GSR) at Hart 2019 – 2022. The blue dashed line is Hart's average GSR (300 mm). The orange dashed line is average annual rainfall (400 mm).

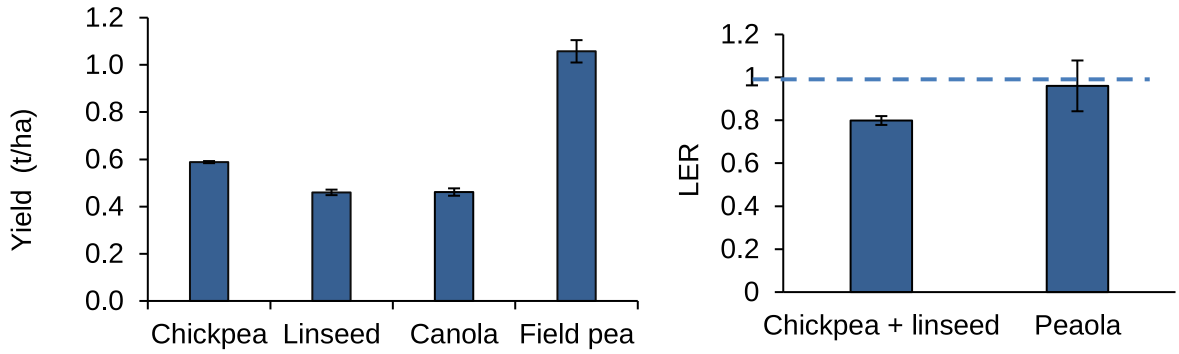


Figure 3. Grain yield of monocrops (left) and LER of intercrops (right) at Hart in 2019. The dashed blue line displays an LER value of 1.0. This figure has been adapted from Parvin, 2020.

At Hart in 2022, excellent grain yields were noted for monocrops, with canola yielding 1.95 t/ha and pulses between 2.65 – 4.06 t/ha. Canola yield was reduced when intercropped with field pea, vetch, lentil, faba bean or chickpea, indicating reduced productivity from the intercrop system (Figure 4). Canola intercropped with legume treatments provided grain yields between 1.05 – 1.38 t/ha.

Pulse and legume sown as a sole crop outperformed all comparative intercropping treatments (Figure 5). Legume treatments intercropped with canola yielded only 26 – 42% on the sole crop yield (Table 3). Chickpea and lentil production was also significantly reduced when intercropped with canola, yielding only 0.74 – 0.95 t/ha, indicating these crop types have reduced crop competition. Similar results were observed in a study conducted in 2019, showing no yield benefits were observed by intercropping chickpea with canola or linseed (P Roberts 2020).

When intercropped together, faba bean and lentil provided similar yields to their comparative monocrop treatments (data not shown). Anecdotal evidence suggests that intercropping these two species together provides ground cover benefits in low rainfall areas.

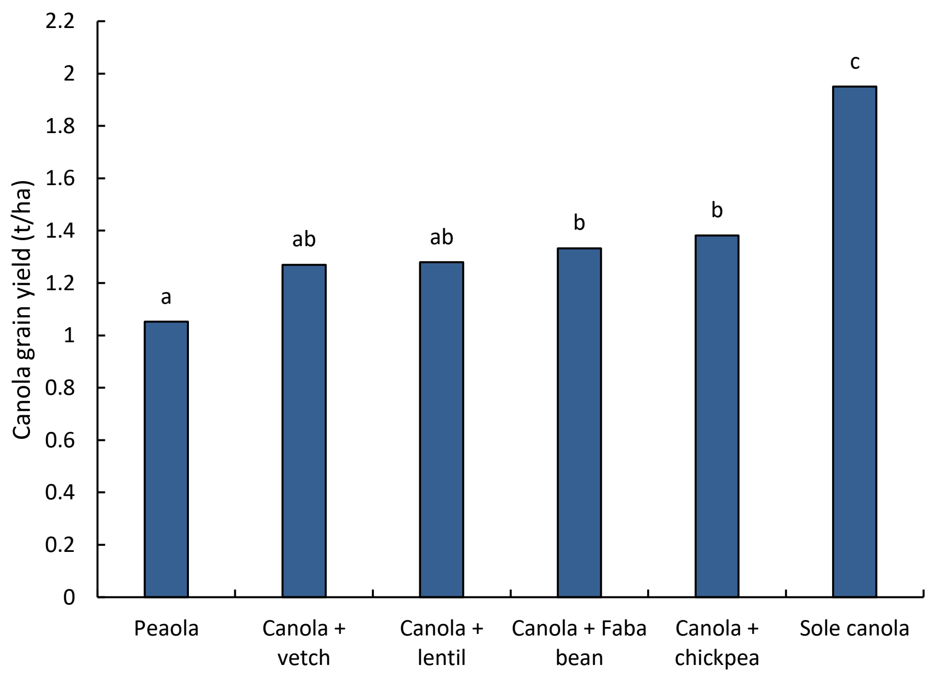


Figure 4. Grain yield of sole (monocrop) canola (t/ha) in comparison to canola intercropped with field pea, vetch, lentil, faba bean or chickpea at Hart in 2022. Columns with the same letters are not significantly different (P value = 0.002).

Table 3. Grain yield (t/ha), yield difference (t/ha) and % yield for crop types in comparison to their monocrop treatment at Hart in 2022.

Intercropping treatment	Crop type	Yield (t/ha)	Yield difference (t/ha) to comparative sole crop	% Yield (expressed as % of comparative monocrop average)	% of total intercrop yield
Peaola	Canola	1.05	-0.90	54	49.2
	Field pea	1.09	-1.71	39	50.8
Chickpea + canola	Chickpea	0.74	-2.15	26	34.8
	Canola	1.38	-0.57	71	65.2
Faba bean + canola	Faba bean	1.33	-0.58	33	50.8
	Canola	1.29	- 0.66	66	49.2
Lentil + canola	Lentil	0.95	-2.96	24	42.7
	Canola	1.28	- 0.67	66	57.3
Vetch + canola	Vetch	1.10	-1.55	42	46.5
	Canola	1.27	0.22	65	53.5
Faba bean + lentil	Faba bean	1.92	-2.14	47	59.4
	Lentil	1.31	-2.60	33	40.6

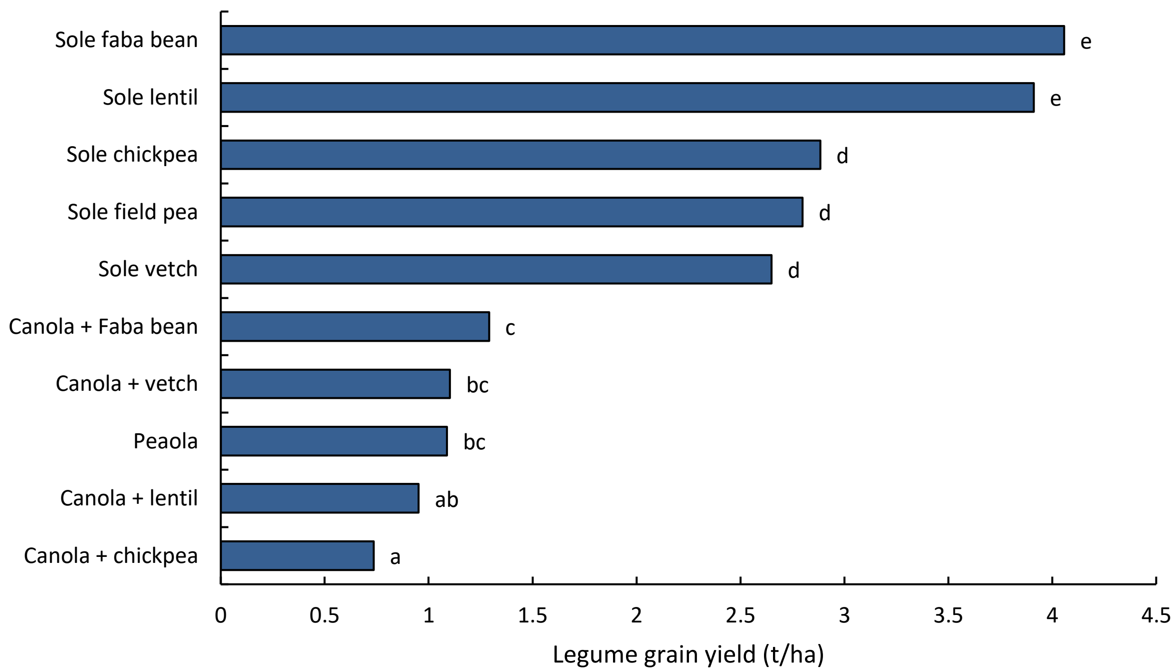


Figure 5. Grain yield of sole legumes (t/ha) and legumes intercropped with canola. Bars with the same letters are not significantly different (P value = <0.001).

In 2022, harvest index (HI), was similar for canola sown either as monocrop or intercrop, indicating that the ratio of harvested seed weight to total above ground biomass was similar for all treatments. Faba bean and vetch performed similarly to their comparative intercrop, with a HI of 0.61 and 0.52 respectively (total grain yield = 52 – 61% of total crop biomass). Sole field pea, lentil and chickpea had a higher HI when compared to intercrop treatments, indicating a higher amount of grain (t/ha) was produced these sole treatments, this trend is also observed in yield data (Figure 5).

Grain quality

Canola oil (%) was high across all treatments at Hart in 2022, ranging from 47.8 – 49.43%, however differences across monocrop and intercrop treatments were observed (P value = 0.03). The sole canola treatment, canola + lentil, canola + faba bean and canola + chickpea had the highest oil cotent, with an average of 48.9%. Although faba bean yield was reduced through intercroppping, seed size increased when intercropped with canola. Chickpea seed size was also reduced by 8% when intercropped due to poor crop competition when sown with a secondary crop species. All other crop types performed similarly to their comparative monocrop in 2022 (data not shown).

LER

Intercropping treatments at Hart in 2022 had LER values ranging from 0.81 – 1.07. This indicates that grain yield was reduced when two crop species were grown together, compared to their sole crops (Figure 6). The only treatment to provide yield increases with an LER > 1 was the canola and vetch intercropping treatment. Other studies from the region have typically found LER values of 1.1 to 1.8 for various canola-legume combinations (Roberts et al. 2017), which is typical of findings from overseas temperate cropping systems (Dowling et al. 2021). The reason for lower LER values at Hart in 2022 compared to other studies in the region (Roberts et al. 2017) are not known, however, in addition to the soils and climate of a region, factors including row intercrop planting configurations and the compatibility of the cultivars grown can affect yield outcomes.

If consistent yield benefits from intercropping cannot be achieved, other benefits will be needed to compensate for the increased complexity of operations. Future studies should examine the potential for reductions in nitrogen fertiliser use or fungicide use in intercropping systems, and any soil legacy effects that may improve subsequent cereal crop yields.

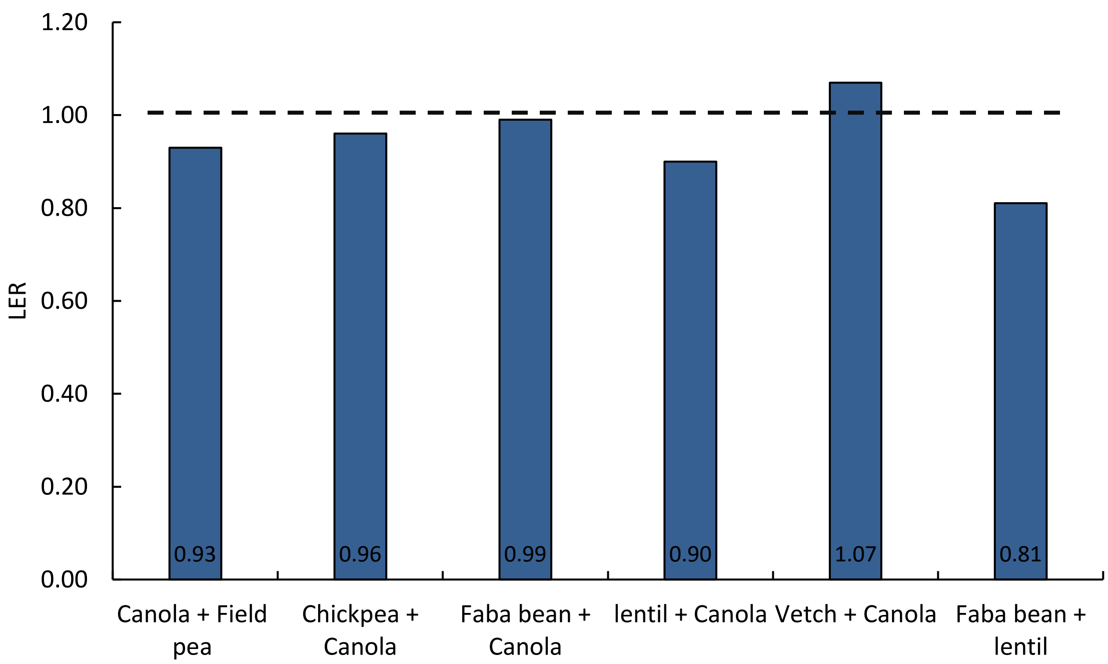


Figure 6. Land equivalent ratio (LER) of intercrop treatments at Hart in 2022. The dashed line displays an LER value of 1.0 (representing sole crop treatments).

Wheat grain yield and NDVI

Wheat grain yields at Hart in 2020 were similar for all previous intercrop and monocrop treatments. This indicates intercropping treatments did not increase wheat grain yield relative to the individual crops (Parvin 2020). This result was also observed at Hart in 2022, with an average wheat yield of 3.5 t/ha. Grain quality was also similar across all treatments. No differences in wheat vigour, measured as NDVI, were observed (P=0.113) in 2022, resulting from intercrop or monocrop treatments.

Soil water

In 2019, there were minimal differences in soil water for all crop types (data not shown). The intercropping treatments were able to draw down and access more soil water in late winter months, however once the profile was full, similar observations for water dynamics were observed. This was an unexpected result due to varying root dynamics of selected crop types. In the consecutive year's wheat crop, no difference in residual soil moisture was observed. (Parvin 2020). Despite wetter seasonal conditions at Hart in 2021, similar soil water use was observed for all monocrop and intercrop treatments measured (Figure 7).

Water use trends were similar in the 2022 cereal phase for all monocrop and intercrop treatments, suggesting no residual effects from the previous season's pulse crops influenced infiltration. There is evidence to suggest chickpea roots did not penetrate as far into soil as other pulse treatments, as it was the only crop to not show root activity at 55 cm.

Figure 7. Soil water content measured by capacitance probes (EnviroPro 80 cm EP100GL-08) presented as the average for (top to bottom) for canola + faba bean, field pea, canola, canola + chickpea, chickpea and peaola treatments at Hart in 2021.

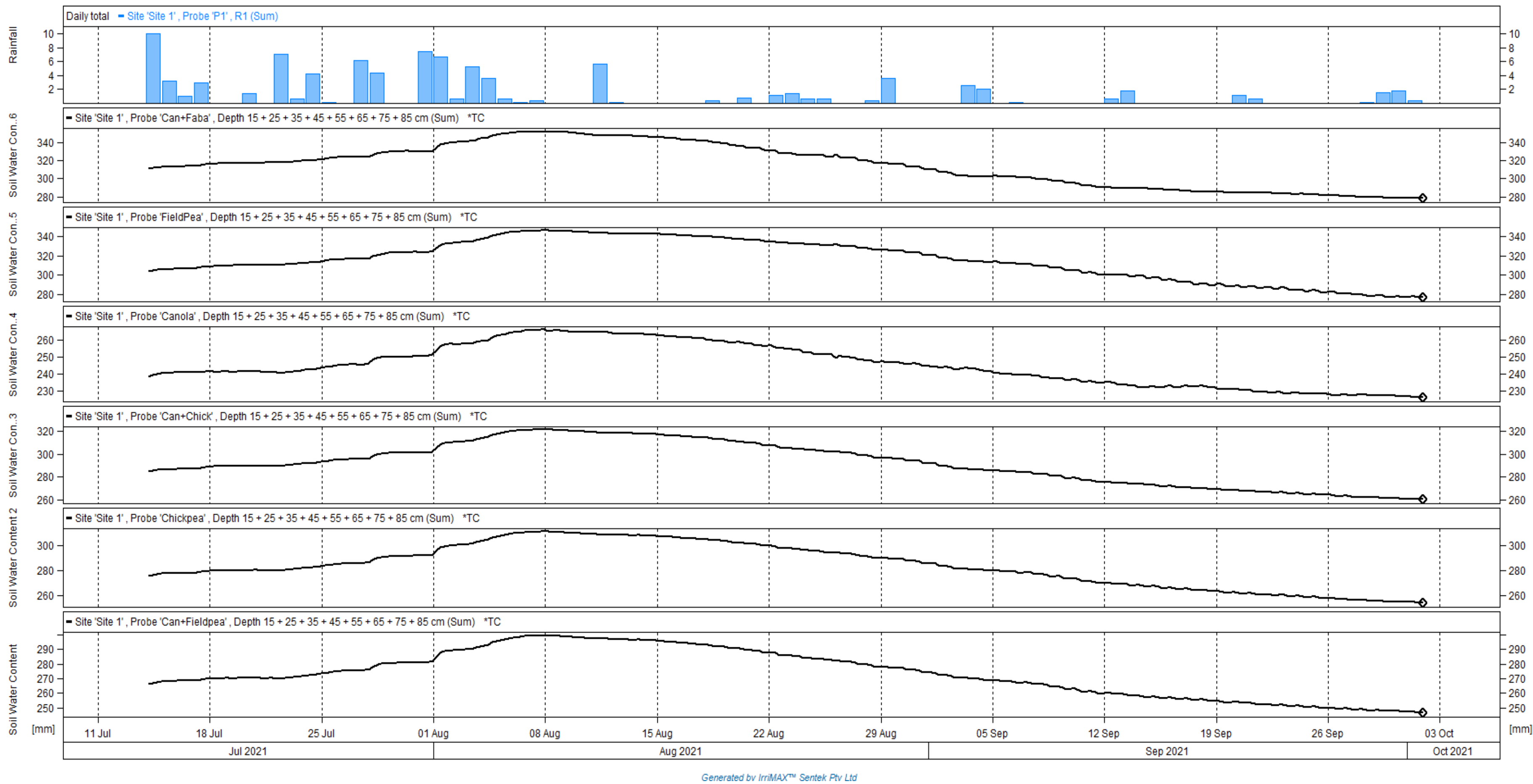
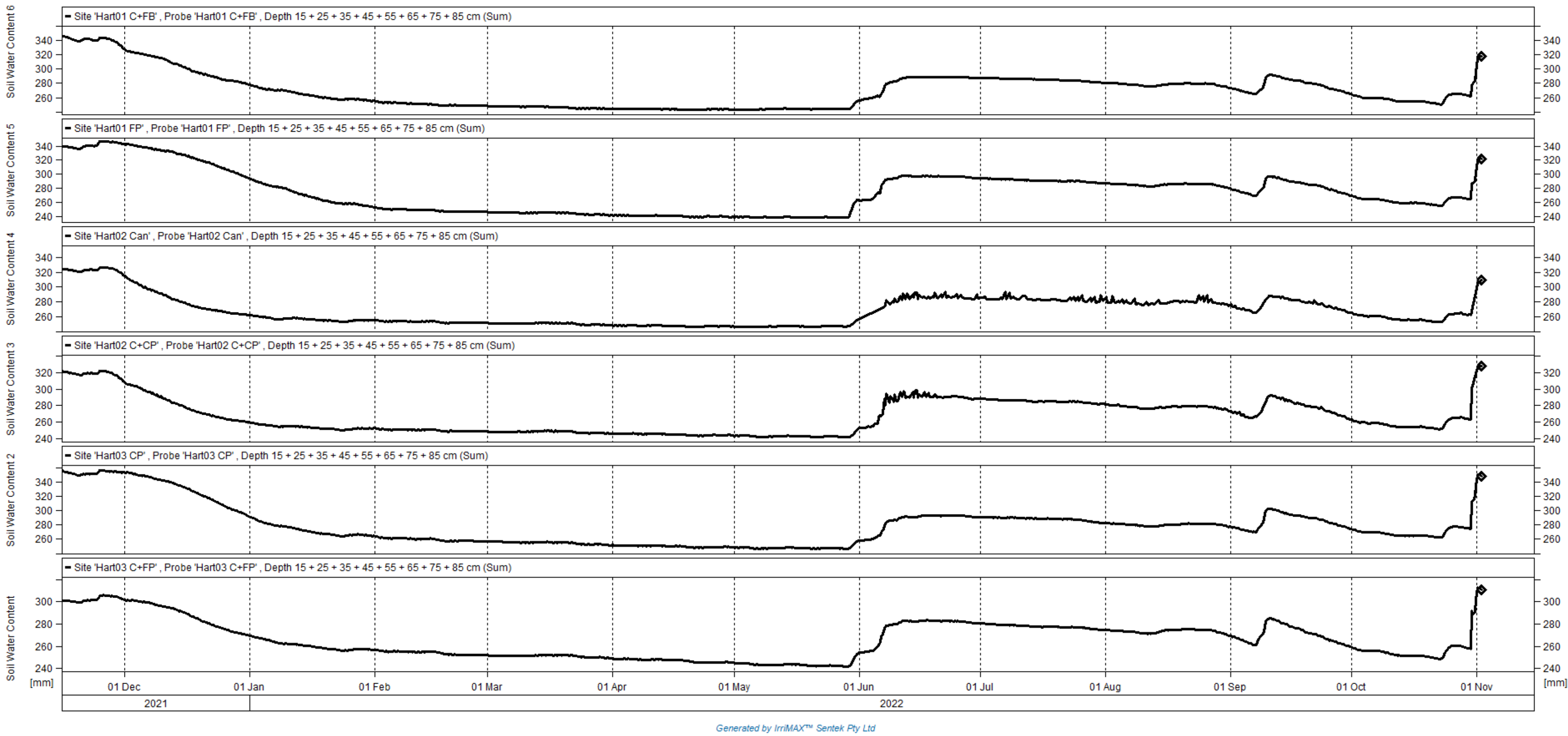


Figure 8. Soil water content measured by capacitance probes (EnviroPro 80 cm EP100GL-08) in canola + faba bean, field pea, canola, canola + chickpea, chickpea and peaola plots, over sown to Scepter wheat in 2022.



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References

Fletcher A, Kirkegaard J, Condon G, Swan T, Greer K, Bremer E, Holding J 2020. The potential role of companion and intercropping systems in Australian grain farming. Should we be considering them?, GRDC Update papers
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2020/02/the-potential-role-of-companion-and-intercropping-systems-in-australian-grain-farming.-should-we-be-considering-them

Kirkegaard J, Condon G 2019. Companion cropping – should we be considering it?, GRDC Update papers
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/companion-cropping-should-we-be-considering-it

Parvin S, Noack S, Rose T, Allen R 2020. Evaluating cropping systems, 2020 Hart Trial Results Book
https://www.hartfieldsite.org.au/media/2020 Trial Results/2020_Hart_Trial_Results_Evaluating_intercropping_systems.pdf

Roberts P, Dowling A 2020. Intercropping – a tool to improve profitability in broadacre systems, 2020 Hart Field Day Guide
https://www.hartfieldsite.org.au/media/2020 FIELD DAY GUIDE/HFDG2020_T_Intercropping-A_tool_to_improve_profitability_in_broadacre_systems.pdf