Farming systems: profit, water, nutritional and disease implications of different crop sequences and system intensities in SNSW

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Take home message

- Southern NSW growers and consultants were consulted for 12 months (2017) to establish four state-of-the-art farming systems research sites targeting the next step changes in WUE and farm profit
- For the first time, interactions of crop sequence, early sowing systems (with and without grazing) and nitrogen fertiliser strategies were established and monitored for WUE, production and profit
- Results to date from two consecutive decile 1 seasons (2018 and 2019) have shown that the 2-year average annual earnings before interest and taxes (EBIT) ranged from -$50 to $1000/ha across the sites, and at all sites there were options that outperformed the Baseline (canola-wheat sequences) by $200 to $500/ha
- Under the dry conditions, grazing crops and barley were highly profitable at all sites, but there were also legume options at all sites that outperformed baseline wheat and canola sequences
- Legacy effects of water and N generated by both crop choice (legumes) or fertiliser strategy increased profit in subsequent crops by $200-$300/ha due to increased grazing, hay or grain.

Background – changing the WUE paradigm from crop to crop sequence

Australian farmers have been enthusiastic adopters of crop benchmarking tools (such as French and Schultz or Yield Prophet®) to compare the performance of individual crops to water-limited potential. However, in dryland farming systems, it makes sense to consider the efficiency of water use across the crop sequence, to account for the inevitable legacy effects of one crop to the next (i.e. carry over effects on water, N, weeds and disease). Recent analysis in southern QLD and northern NSW revealed only 30% of paddocks had crop sequences that were achieving >75% of predicted potential, much lower than for individual crops. No similar study has been conducted in southern NSW, but recent crop sequence studies have shown the value of diversifying the crop sequence to maintain profit and manage biotic constraints. The average annual gross margins of the best 3 to 4-year sequences was often $400/ha higher than the worst, and $150 to $200/ha better than common sequences, even when individual crops were well managed (see Further Reading).

In addition to improved crop sequences, new early sowing systems are proving efficient and profitable for individual wheat and canola crops (including grazed crops), but the legacy of dry soils left by these higher-yielding crops across the sequence may affect following crops. Preliminary simulation studies in southern NSW suggest earlier sowing strategies can provide benefits across the crop sequence, but this is influenced by rainfall, crop sequence and modified by N management.

No previous study has investigated the interactions of crop sequence choices, sowing time and N supply on efficiency and profitability across a whole sequence. Our project, now in its third year, is investigating these interactions to develop strategies to convert annual rainfall into more profit across a crop sequence while managing costs, risk, soil fertility, weeds and diseases.

The Southern Farming Systems Project

This project builds on recent GRDC projects in southern NSW and on a sister project that commenced earlier in northern NSW and QLD (Zull et al., 2020). During 2017, we reviewed the existing literature, conducted a comprehensive survey of growers and agronomists and established sites with sequence, sowing date and N treatments relevant to local growers and advisors.

To cover the range of soil and climate in southern NSW, sites were established at Wagga Wagga (core site), Greenethorpe (higher rainfall), Condobolin (lower rainfall) and Urana (different soil type). A range of different sequences were established to compare with the common baseline of canola-wheat sequences (Table 1). These included more intensive cereal sequences (wheat and barley), a range of high (lentil, chickpea) and low-value (lupin, faba) legume options as well as grazing and forage options. These treatments generate different water and N-use patterns as well as weed, disease and cover legacies monitored by the team.

In addition, for some sequences, we included interactions of early sowing (March-early April) and timely sowing (mid-April-mid May) of wheat and canola options (grazed and ungrazed), and different N management strategies based on either Decile 2 or 7 outlooks for spring. These treatments, developed with local advisers generated a range of different management and sequence decisions to influence the pattern of water and N use as well as the cost, risk and ultimately the efficiency of the system ($/ha/mm). In addition to the planned and phased sequences, we included “flexible” treatments managed by local advisors, where they nominated the crops and their management.

Together with the experimental measurements we are running APSIM simulations to extrapolate the results across more sites and seasons, and to update pre-experimental modelling predictions with validated data. This combination of multi-site experiments and simulation will provide powerful insights to the drivers of higher systems efficiency.

Table 1. Treatment summary - including crop sequence, time of sowing and N strategy from the Wagga Wagga core experimental site. A subset of these treatments relevant to the other sites were established according to local grower and consultant advice. Common treatments at all sites are shown in grey.

Treatment description	Sequence	Sowing time	N strategy (Decile 2 or 7)	Grazing
Baseline	Canola-wheat-barley	Timely	2, 7	
Intense Baseline	Canola-wheat	Early, timely	2, 7	Yes
Diverse high value 1	Lentil-canola-wheat	Early, timely	2, 7	
Diverse high value 2	chickpea-wheat	Timely	2	
Diverse low value	(Faba/lupin)-canola-wheat	Timely	2	
Diverse (mix)	HDL*-canola-wheat	Early, timely	2, 7	Yes
Continuous wheat	Wheat-wheat-wheat	Timely	2, 7	
Fallow	Fallow-canola-wheat	Early, timely	7	
Intercrop	Mixed species#-wheat	Timely	2	
Ley phase	Biserrula-wheat	Timely	2	Yes
Flexible	e.g. Safflower-barley-chickpea	Flexible	Flexible	
Intense baseline + organic matter (OM)	Canola-wheat	Timely	2	

*HDL= high density legume mix (vetch, arrowleaf clover, balansa clover)
Intercrop mixed species = 2018, 2019 (mix of faba bean/canola); 2020 (mix of linseed/chickpea)

Key outcomes to date

The context – dry conditions in 2018-2019

As most sequences involve 3-year phases, a full statistical analysis of the sequences is not yet possible. In addition, the 2018 and 2019 seasons have been consecutive decile 1 seasons, so that most of the responses measured to date are relevant to the context of very dry, low rainfall seasons. In 2018, early sown options received small amounts of supplementary irrigation (<10mm) to establish crops, while at Condobolin in 2019, irrigation was required to keep the experiment viable. The amount of rainfall at each site across the two seasons and the long-term mean are shown in Table 1.

Table 2. Rainfall (irrigation in brackets) at the experiment sites in 2018 and 2019 and the long-term median rainfall.

Site	2018	2019	LTM
Greenethorpe	359	353	579
Wagga Wagga	286	320	526
Urana	276	222	449
Condobolin	218 (120)	162 (118)	434

Despite the consecutive decile 1 seasons, all planned treatments were successfully established in both years, and given that context, some general observations across the sites, as well as some more specific observations emerging from the sites are presented here.

Annual profits (EBITs) varied widely - some options made good profits despite the conditions

Despite the decile 1 conditions, the annual earnings before interest and taxes (EBITs) for different crop options varied from -$500 to $1700/ha in 2018, and -$500 to $1200/ha in 2019, with the 2yr average annual EBITs varying from $-50 to $1000/ha across the sites (Figures 1, 2, 3, 4). The high profits overall were underpinned by good fallow management to preserve the summer rain that fell (strict weed control and stubble retention), and the timely and successful establishment of good plant populations across the sites.

Grazed crops were highly profitable

Early-sown grazed treatments (dual-purpose canola and wheat in Intense Baseline) were among the most profitable treatments at Greenethorpe and Wagga Wagga where they were included. (Figure 1, 2). This was the case in both years at Greenethorpe, while at Wagga Wagga in 2019, the earlier onset of stress limited biomass for grazing and regrowth after grazing (Table 3). However, at both sites, the early-sown dual-purpose wheat and canola crops were significantly more profitable than either early or timely-sown grain-only crops (un-grazed Intensive Baseline, Baseline), as the grazing provided significant income in these dry years where grain production was limited, and livestock prices were high.

The success of the dual purpose (DP) crops largely depended on an early sowing opportunity, and on deep stored water from either summer rainfall and good fallow management, or sequences with legumes (e.g. Diverse Mixed) which left legacies of water and N. At Greenethorpe, consecutive early-sown DP crops were able to capitalise on higher amounts of stored water to produce more than 3 times the profit achieved by the grain only (or hay) system **($1122/ha vs $334/ha)** (Figure 2, Table 3). At Wagga Wagga under drier conditions, income for the same DP crops declined in the second year (2019) due to legacies of drier soil, but still had higher profit than the grain-hay system ($379/ha vs $172/ha) (Figure 1, Table 3). More information on the DP crops can be found in Kirkegaard et al., (2020 a,b).

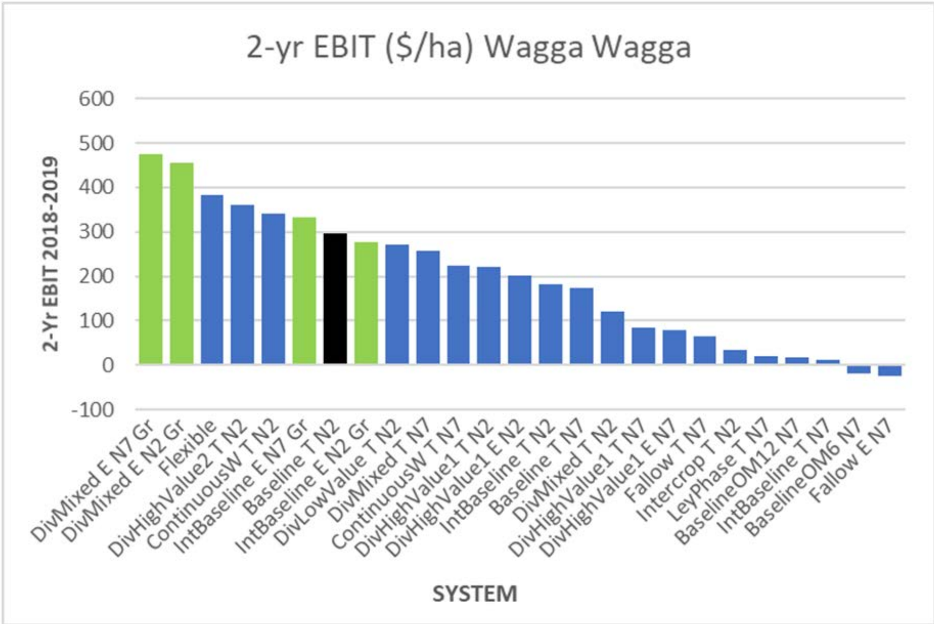

Figure 1. Two-year average annual EBIT for different treatments at Wagga Wagga. The Baseline treatment [canola-wheat-barley; timely sown; decile 2 N] is shown in black. Early sown grazed treatments are shown in green and were among the most profitable for the 2018-2019 seasons. Grazed sequences involving legumes (Diverse; Div) were more profitable than Intense Baseline (C-W only) as the legume was grazed, and also left legacies of water and N for the early-sown canola and wheat (see Table 1 for treatment descriptions). (T=Timely. N2 and N7 refers to nitrogen strategy for a decile 2 or 7 season. Gr=grazed. Div=Diverse. Int=Intense.)

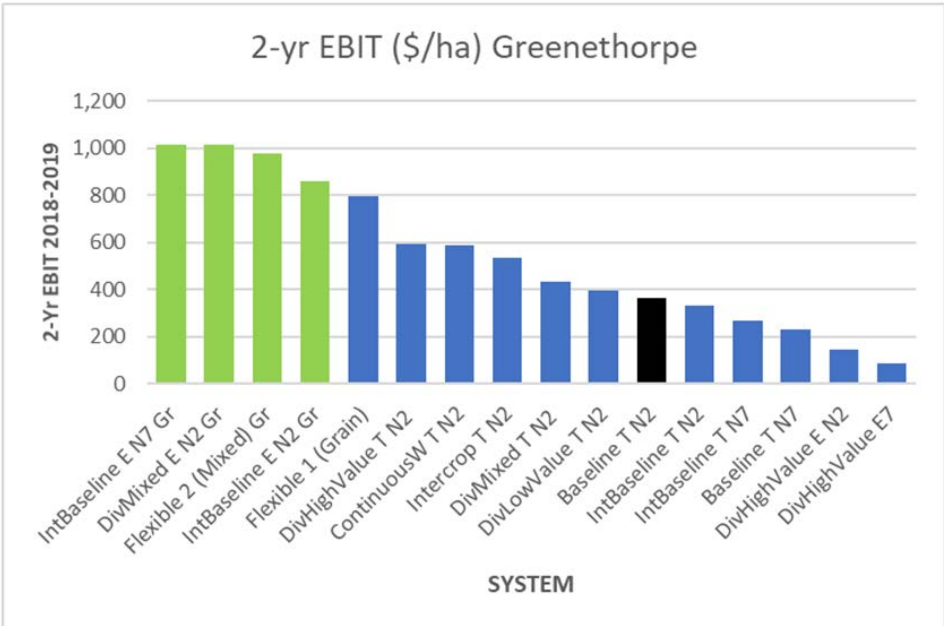

Figure 2. Two-year average annual EBIT for different treatments at Greenethorpe. The Baseline treatment [Canola-Wheat-Wheat; timely sown; Decile 2 N] is shown in black. Early sown grazed treatments are shown in green and were the most profitable for the 2018-2019 seasons. Numerous treatments were more profitable than the Baseline during 2018 and 2019. In general, the decile 2 N strategy was more profitable due to the drought (see Table 1 for treatment descriptions). T=Timely. N2 and N7 refers to nitrogen strategy for a decile 2 or 7 season. Gr=grazed. Div=Diverse. Int=Intense.)

Table 3. Annual and 2-year profit (earnings before interest or taxes - EBIT) at Greenethorpe and Wagga Wagga for early-sown (March) dual- purpose canola-wheat systems compared with timely sown (April) canola-wheat grain-hay systems in 2018 and 2019. Systems were phased (both crops were grown in each year).

Site/Crop	Dual-purpose system				Grain only system		
	Variety (sowing date)	Graze (t/ha)	Grain (t/ha)	EBIT ($/ha)	Variety (sowing date)	Grain/ (Hay) (t/ha)	EBIT ($/ha)
Greenethorpe							
2018 Wheat	LRPB Kittyhawk⦸ (5/4)	1.5	1.9	$862	Coolah⦸ (7/5)	2.7	$619
2019 Canola	Hyola®970 (23/3)	5.0	0	$1,414	HyTTec Trophy® (1/5)	(3.1)	$96
Ave 2-Yr EBIT				***$1,138***			***$358***
2018 Canola	Hyola970 (3/4)	3.5	0.9	$1,251	HyTTec Trophy (7/5)	1.1	$79
2019 Wheat	DS Bennett⦸ (26/3)	3.5	0	$960	Coolah⦸ (1/5)	(4.8)	$538
Ave 2-Yr EBIT				***$1106***			***$309***
Average 2-yr system EBIT				**$1122**			**$334**
Wagga Wagga							
2018 Wheat	LRPB Kittyhawk⦸ (3/4)	2.0	1.9	$974	Beckom⦸ (2/5)	2.1	$333
2019 Canola	Hyola970 (8/4)	2.7	0	$78	Pioneer 43Y92 CL (26/4)	1.1	$124
Ave 2-Yr EBIT				***$526***			***$229***
2018 Canola	Hyola970 (3/4)	3.1	0	$347	Pioneer 43Y92 CL (3/4)	1.2	$34
2019 Wheat	LRPB Kittyhawk⦸ (8/4)	2.8	0	$114	Beckom⦸ (6/5)	(3.5)	$198
Ave 2-Yr EBIT				***$231***			***$116***
Average 2-yr system EBIT				**$379**			**$172**

Grain legumes performed well at most sites

Grain legumes (fababean, lentil, lupin, pea and chickpea) and pasture legumes (vetch) performed well across the sites in both years and were never the least profitable crop option (Table 4). In 2018, they produced the highest non-grazed EBITs which were at or above $1,000/ha at 3 of the 4 sites. In 2019, the fababean at Urana and pea at Condobolin performed very well (among the most profitable options), while lentil and chickpea did not perform as well in 2019, but they generated moderate EBITs. In all cases there were legume options that outperformed canola and wheat at the sites. Diverse sequences (i.e. those that included a legume) also made higher 2-year profit then the Baseline treatments at all sites and were among the most profitable even when not grazed (Figures 1 to 4).

The grain legumes also left legacies of higher water and N in the soil at harvest. Compared to early-sown wheat or canola, there was 20mm more water and 50 kg/ha more N in 2018, and up to 60mm more water and 50-100 kg/ha more N in 2019. These legacy effects of the 2018 grain legumes on 2019 crops are discussed in the next section.

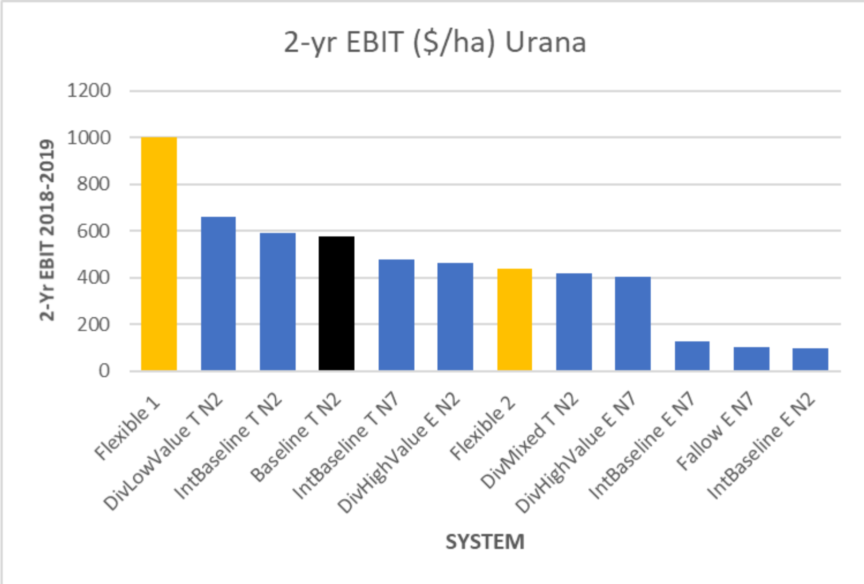

Figure 3. Two-year average annual EBITs for different treatments at Urana. The Baseline treatment [Canola-Wheat-Barley; timely sown; Decile 2 N] is shown in black. The highly profitable "Flexible" treatment was a safflower-barley sequence nominated by the grower. Early sown un-grazed treatments, and treatments including fallow had low profit. The Diverse treatment with low value legume (fababean-canola-wheat) was more profitable than the Baseline. (See Table 1 for treatment descriptions). (T=Timely. N2 and N7 refers to nitrogen strategy for a decile 2 or 7 season. Gr=grazed. Div=Diverse. Int=Intense.)

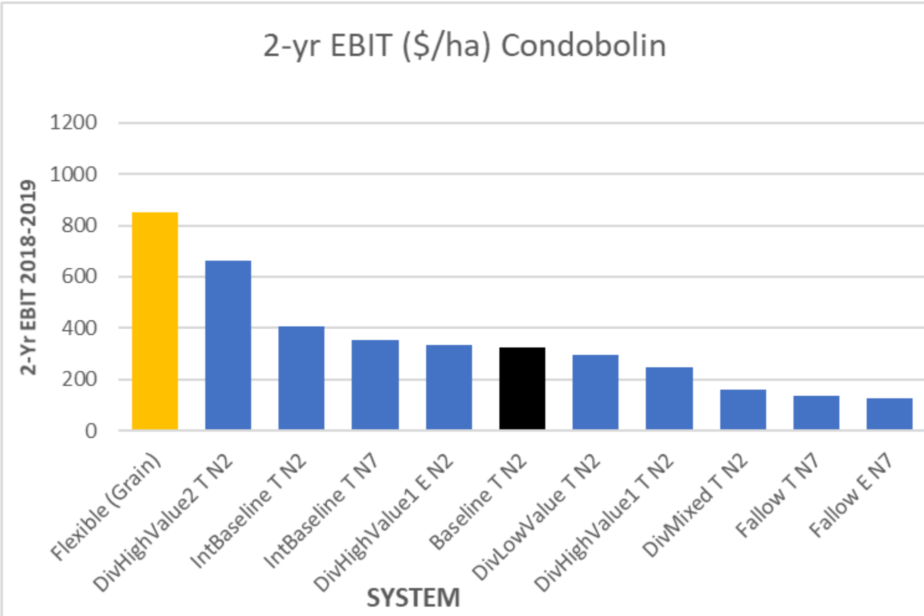

Figure 4. Two-year average annual EBIT for different treatments at Condobolin. The Baseline treatment [canola-wheat-barley; timely sown; decile 2 N] is shown in black. The highly profitable "Flexible" treatment was a barley-fieldpea sequence nominated by the consultant. The Diverse high value sequence (chickpea-wheat) was also highly profitable while the Fallow sequence (fallow-canola-wheat) had low profit as the low rainfall over both seasons meant poor fallow efficiency. (See Table 1 for treatment descriptions). (T=Timely. N2 and N7 refers to nitrogen strategy for a decile 2 or 7 season. Gr=grazed. Div=Diverse. Int=Intense.).

Table 4. Yield and profit achieved by different legume options across the sites in 2018 and 2019 compared to timely-sown wheat and canola crops (decile 2N) in Baseline treatments (grey). Legume options that are more profitable than both wheat and canola in each case are shown in bold.

Site/crop	Year 1 - 2018			Year 2 - 2019		
	Variety (Sow date)	**Yield (t/ha)**	**EBIT $/ha**	**Variety (Sow date)**	**Yield (t/ha)**	**EBIT $/ha**
Wagga Wagga						
Chickpea	PBA Slasherⓑ (10/5)	1.3	**$499**	PBA Slasherⓑ (13/5)	0.5	$87
Lentil	PBA HallmarkXTⓑ (10/5)	1.4	$313	PBA HallmarkXTⓑ (13/5)	0.7	$120
Lupin	Batemanⓑ (10/5)	1.6	**$338**	Batemanⓑ (13/5)	1.3	**$353**
Canola	*43Y92 CL (2/5)*	*1.2*	*$34*	*43Y92 CL (26/4)*	*1.3*	*$203*
Wheat	*Beckomⓑ (2/5)*	*2.1*	*$333*	*Beckomⓑ (6/5)*	*1.3*	*-$6*
Greenethorpe						
Chickpea	PBA Slasherⓑ (8/5)	1.9	**$996**	PBA Slasherⓑ (14/5)	1.2	$278
Lentil	PBA HallmarkXTⓑ (8/5)	1.7	$589	PBA HallmarkXTⓑ (14/5)	0.9	-$51
Fababean	PBA Samiraⓑ CL (9/5)	2.1	**$1029**	PBA Samiraⓑ (15/5)	2.3	**$406**
Canola	*InVigor® T4510 (7/5)*	*1.1*	*$43*	*HyTTec® Trophy (1/5)*	*1.2*	*$34*
Wheat	*Coolahⓑ (8/5)*	*2.7*	*$650*	*Coolahⓑ (1/5)*	*2.4*	*$337*
Urana						
Chickpea	-	-	-	PBA Slasherⓑ (16/5)	(2.4 hay)	$185
Lentil	PBA HallmarkXTⓑ (8/5)	2.2	**$992**	PBA HallmarkXTⓑ (16/5)	1.3	$371
Fababean	PBA Samiraⓑ (8/5)	1.8	**$970**	PBA Samiraⓑ (16/5)	2.0	**$987**
Canola	*43Y92 CL (30/4)*	*1.9*	*$573*	*43Y92 CL (30/4)*	*1.1*	*$201*
Wheat	*Beckomⓑ (30/4)*	*2.1*	*$558*	*Beckomⓑ (30/4)*	*2.7*	*$735*
Condobolin						
Chickpea	PBA Slasherⓑ (22/5)	2.0	**$1328**	PBA Slasherⓑ (22/5)	0.9	**$235**
Lentil	PBA HallmarkXTⓑ (22/5)	1.3	$349	PBA HurricaneXTⓑ (22/5)	0.9	$92
Lupin	Batemanⓑ (22/5)	2.0	**$863**	Batemanⓑ (22/5)	0.4	-$187
Fieldpea	-	-	-	Ouraⓑ (22/5)	1.8	**$459**
Canola	*InVigorT 4510 (2/5)*	*1.2*	*$151*	*HyTTec Trophy (22/5)*	*0.8*	*$19*
Wheat	*Beckomⓑ (1/5)*	*2.4*	*$681*	*Beckomⓑ (22/5)*	*1.6*	*$144*

Legacy effects of legumes and their impacts

The legacy effects of the 2018 legumes on 2019 crops were in some cases quite significant and related to the carryover of N, water or both, which influenced the yield and profit of the 2019 crops

(Table 5). Evidence for significant legacy effects were obvious at all sites, often generating increases in subsequent EBITs of up to $200-$300/ha due to either increased grazing, hay or grain yield.

For example, at Greenethorpe in 2019, the early-sown dual-purpose canola produced 4.0 t/ha of forage for grazing when sown after high density grazed legume (vetch), compared to 3.6 t/ha after grazed wheat. This was presumably due to more water (59mm *vs* 31mm) and nitrogen (82 kg N/ha *vs* 41 kg N/ha) left in the profile at harvest in 2018. Similarly, at Wagga Wagga, the yield of timely canola after wheat (decile 2 N) was 1.1 t/ha, compared to 1.7 t/ha after lentils with an associated increase in EBIT from $124/ha to $389/ha. The decile 7 timely canola had an intermediate yield of 1.4 t/ha and EBIT of $210, suggesting at least some of the difference between the legume and canola pre-crops could be related to N, but more likely to water, as lentils are known to be shallower rooted and leave more residual water than canola. At Urana, the timely canola with decile 2 N yielded 1.0 t/ha after wheat compared to 1.5 t/ha after lentil, with the EBIT increasing from $187 to $443 as a result. A higher N level on the 2019 canola did not increase the yield or EBIT, suggesting residual water after the lentils rather than N was the primary driver. At Condobolin, the timely wheat (decile 2 N) in 2019 yielded 1.7 t/ha after canola but 2.2 t/ha after chickpea, with EBIT increasing from $165/ha to $354/ha. The timely wheat decile 7N yielded 1.9 t/ha and EBIT was $238.

Table 5. Some of the yield and profit increases in 2019 crops related to legume pre-crops in 2018 and the residual plant available water (PAW) and N left at harvest.

Site	2018 Crop			2019 Crop		
	Crop Type	**Residual N (kg/ha)**	**Residual PAW (mm)**	**Crop**	**Yield (t/ha)**	**EBIT ($/ha**
Greenethorpe	HDL (vetch)	82	59	Hyola970	4.0 (forage)	$1,073
	Wheat - Manning⦸	24	31	Hyola970	3.6 (forage)	$1,015
Wagga Wagga	Lentil - HallmarkXT⦸	-	24	43Y92 CL	1.7	$389
	Wheat - Beckom⦸	-	16	43Y92 CL	1.1	$124
Urana	Lentil - HallmarkXT⦸	-	-	43Y92 CL	1.5	$443
	Wheat - Beckom⦸	-	-	43Y92 CL	1.0	$187
Condobolin	Chickpea - Slasher⦸	70	19	Beckom⦸	2.2	$354
	Canola – 43Y92	33	18	Beckom⦸	1.7	$165

Responses to nitrogen fertiliser strategies

There were few yield responses to the higher N treatment (decile 7 *vs* decile 2) in 2018, and in some cases yield reductions, presumably due to haying off. However, soil tests revealed higher levels of post-harvest N carryover in the decile 7 treatments and these had impacts on the biomass, hay and in some cases grain yields of the 2019 crops, despite the dry conditions. Positive responses to higher N were generally in grazed biomass or hay (e.g. at Greenethorpe the Intensive baseline early-grazed canola provided 5.0 t/ha at 7N but only 3.6 t/ha at 2N; and in the un-grazed Intensive baseline wheat, the hay cut was 5.1 t/ha vs 4.8 t/ha). For grain-only crops there was either no response or a negative response to higher N (e.g. Greenethorpe Baseline timely sown decile 2N produced 2.4 t/ha while decile 7 N produced 2.1 t/ha). At Condobolin, the early-sown wheat after canola hayed-off in the decile 7 N treatment, producing only 0.8 t/ha grain yield compared to 1.8 t/ha in Decile 2 N treatment. Haying off with higher N reduced the EBIT from +$226/ha to -$150/ha. In general, across the 2-year EBITS, the decile 2 N tended to be more profitable than the decile 7 (Figures 1-4), due to the increased cost of N with little or no responses to the additional added fertiliser in the N decile 7 treatments in these dry years.

Barley outperformed wheat in both years

In both 2018 and 2019 barley outperformed wheat as a grain-only option. In 2018, timely-sown barley yielded 3.0 to 3.5 t/ha compared with wheat at 2.0 to 2.5 t/ha, and in 2019 barley doubled the yield of wheat at Greenethorpe (4.7 t/ha vs 2.0 to 2.5 t/ha) and Wagga (3.2 t/ha compared to 1.3 t/ha). At Urana, emus attacked the barley during grain fill, but based on biomass at anthesis the estimated yield was 5.0 t/ha compared to 3.1 t/ha for wheat. The decision to ensure all sites were adequately limed for successful growth of pulses may have benefited the barley along with excellent performance of recent varieties. Wheat was generally more profitable than canola and hay was often a more profitable option than grain, especially for canola.

Hay was a good option for some crops

For un-grazed crops, hay became a very good option due to the significant early biomass accumulated as a result of good stored summer rainfall, combined with the poor winter and spring rainfall and the high prices for hay. A comparison of hay and grain options was presented at the Wagga Wagga Update by Graeme Sandral (see further reading).

Impacts of management decisions on cover levels

During these consecutive dry seasons, the value of summer ground cover on water conservation and especially the opportunity for successful early sowing became evident. Decisions that influence the level of cover include crop choice (cereals>canola>legumes); the level of grazing and lock-up times - especially where crops are 'grazed out'; and the decision to cut hay. The impact of cover on the amount of water stored near the surface and the rate of surface drying during the dry autumns in 2018 and 2019 was stark. We measured the levels of cover on the soil in March 2020 across the sites, and at Greenethorpe. Levels of cover varied from 0.9 t/ha up to 9 t/ha depending upon the management choices made in the preceding two years. Happily, the autumn rainfall in 2020 came early and regularly and was not a significant issue for crop establishment, but the increasing incidence of dry autumn periods and the clear benefits of the earlier-sown grazed treatments, suggests that maintaining adequate cover to facilitate early sowing opportunities may be a wise management decision in southern NSW.

Conclusion

We have completed two years (both decile 1) of the first three-year phase of selected crop sequences combined with different sowing dates and N strategies. Different options have generated results that varied from losses of $500/ha to profits above $1200/ha depending upon management choices. The 2-year annual average EBITs also showed that many options over the first two years have outperformed the Baseline strategies nominated at each site by $200 to $600/ha and EBITS were up to $1000/ha despite the two dry seasons. Legacy effects could also be worth $200 to $500/ha driven by crop choices and N management strategies.

The 2020 season has been very different to date, with good levels of stored water and above average summer, autumn and winter rainfall, so that the full-3-year analysis will provide a more balanced view as nitrogen and not water may become limiting, and the additional costs of disease control become a more significant part of the economics. Our results indicate that sound management strategies in very dry conditions can still provide good profits to allow a more rapid recovery for businesses when conditions improve.

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Further reading

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Appendix 1: Determining earnings before interest and tax (EBIT)

To calculate the annual EBIT for all treatments, we have initially used the following assumptions/prices.

A. Expenditure

1. All herbicides/fungicides/insecticides, seed dressings, fertilisers, GRDC levies and crop insurance costs were obtained from the annual NSW winter cropping guide or the annual SAGIT farm gross margin and enterprise planning guides with links at:
    i. https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops
    ii. https://grdc.com.au/resources-and-publications/all-publications/publications/2019/farm-gross-margin-and-enterprise-planning-guide
2. All seed was priced according to purchasing as pure treated seed from seed companies. i.e. In 2019, prices used were wheat seed at $1/kg, faba bean seed at $1.20/kg, chickpea seed at $1.80/kg and canola seed ranging between $23-30/kg.
3. All operations costs (sowing, spraying, spreading, haymaking, harvest) were based on the principal that a contractor performed the task. These costs were extracted from the yearly SAGIT Farm gross margin and enterprise planning guides. i.e. In 2019 prices used included sowing at $50/ha, ground spraying at $10/ha, cereal harvest at $70-85/ha, cut/rake/bale hay

at $115/ha, with links at: https://grdc.com.au/resources-and-publications/all-publications/publications/2019/farm-gross-margin-and-enterprise-planning-guide

4. All variety levies for all crops and varieties were determined from the variety central website at: (e.g. for pulses) http://www.varietycentral.com.au/varieties-and-rates/201920-harvest/pulse/

B. Income

1. Wheat, barley and canola grain prices were obtained on the day of harvest from the AWB daily contract sheet for specific regions relating to trial location at: https://www.awb.com.au/daily-grain-prices
2. Pulse grain prices were obtained on the day of harvest from Del AGT Horsham and confirmed with local seed merchants.
3. Hay prices were obtained in the week of baling from a combination of sources including The Land newspaper and local sellers.

Appendix 2: Determining grazing value

To determine the estimated value of grazing the early sown crops, we have used the following formulae:

Winter Grazing Value ($/ha) = Plant dry matter (kg) removed x Liveweight dressed weight (c/kg) x Feed conversion efficiency (0.12) x Dressing % (lambs) x Feed utilisation efficiency (0.75)

Dressed weight and value:

- Lambs = 22.9kg (3 year average of light, heavy and trade lambs)
- Dressed weight = $6.25/kg (3 year average NSW)
- Dressing percentage = 50%

An example of 45kg lambs grazing winter Hyola 970 canola:

3800kg plant DM removed x $6.25 x 0.12 x 50% x 0.75 = $1069/ha

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⍉ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994