Lucerne in the crop rotation

David Watson[1], Simon Falkiner[2] and Cam Nicholson[3]
[1] Agvise Services
[2] Falkiner Ag
[3] Nicon Rural Services

Take home messages

- Autumn removal of lucerne significantly decreased subsequent winter crop yields compared to spring removal of lucerne.
- Crops sown after spring removal of lucerne yielded the same as the crops grown in a continuous crop rotation.
- The crop yield penalty from autumn removal only lasts for one year.
- Apart from Grazon, all other herbicide treatments gave unacceptable lucerne control.
- Cultivation in combination with other herbicides will increase lucerne control by 20 to 30%.

Management implications in a nutshell

- Removal of lucerne in spring is recommended as it provides the opportunity to replenish the soil moisture deficit over summer.
- Autumn removal or poor spring removal will result in a soil water deficit going into the winter cropping phase and most likely a reduction in crop yields.
- Decaying lucerne provided more than 150 kg/ha of nitrogen to the crops in the first year, reducing fertiliser costs by $100/ha.
- Spring removal of lucerne followed by a wheat then canola is likely to be the most profitable rotation.

Background

Lucerne is widely regarded as having a wonderful 'fit' in dryland mixed farming systems. It is a very hardy perennial with the ability to produce large amounts of high quality feed in summer and accumulate significant amounts of nitrogen within the soil profile for future crop use. It can assist in exhausting weed seed banks and managing herbicide resistance and with its deep root system will penetrate hostile subsoils opening them up for future crop use.

While the use of lucerne has been more common in lower rainfall areas, using lucerne in the higher rainfall region is often limited by the perceived negative impacts. The Grain and Graze program set out to identify and improve the fit and management of lucerne in a crop rotation. This is an update of where we have got to so far.

Key questions about lucerne in the crop rotation

- What is the impact of the lucerne phase on subsequent crops regarding yield, quality, soil moisture and nitrogen?
- What is the best time to remove lucerne - spring or autumn?
- What is the best method of removing lucerne?
- What is the best crop rotation following lucerne?
- What are the management implications of these insights from a farming system?

Snapshot of the trials

Eight trials were imposed on a six year old mixed stand of Kaituna and Siriver lucerne at Inverleigh that historically had been grazed and cut. Average lucerne plant densities were 47 plants/m^2 at the start of the trialling.

Grain yield and quality following removal of long term lucerne

Crops were established in 2011 where lucerne had been removed in spring 2010 and autumn 2011. An adjacent site that had been continuously cropped was used as a comparison.

Yields from the continuously cropped site were similar to those in the spring 2010 removed lucerne for the barley in 2011, canola in 2012 and wheat in 2013 (Table 1). This indicates there was no negative impact to the crop in 2011 following lucerne if removal occurred in the previous spring. However autumn removal of lucerne resulted in a yield decline in the first crop after the lucerne removal.

Similar yield declines were measured in wheat and canola in the first crop when comparing an autumn to spring lucerne removal time (Table 2).

Table 1. Comparison of grain yield in 2011 and 2012.

Treatment	2011 barley yield (t/ha)	2012 canola yield (t/ha)	2013 wheat yield (t/ha)
Continuous crop	3.4	2.7	6.8
Spring 2010 removal of lucerne then crop	3.7	2.6	6.9
Autumn 2011 removal of lucerne then crop	2.7	2.9	6.9

Table 2. Grain yield in 2011 and 2012 after different lucerne removal times.

Crop	Time of lucerne removal	2011 yield (t/ha)	2012 yield (t/ha)	2013 wheat yield (t/ha)
Canola	Spring 2010	1.5	2.6	3.2
	Autumn 2011	0.9	2.9	3.1
Wheat	Spring 2010	3.8	3.2	7.0
	Autumn 2011	3.3	3.0	6.9
Barley	Spring 2010	3.7	2.4	7.6
	Autumn 2011	2.7	2.3	8.0

This data indicates a consistent decrease in grain yield with the autumn removal of lucerne compared to a spring removal. The loss in yield was 0.6 t/ha for canola, 0.5 t/ha for wheat and 1.0 t/ha for barley. When all first crops following lucerne removal are combined, the impact of different removal times is highly significant.

The average yield decrease from the canola, wheat and barley was 30% when the lucerne was removed in the autumn of 2011 compared with that removed in spring 2010. This equated to a decrease of 7% a month across the three crops and broadly supports work undertaken by Angus et al (2000) in southern NSW where they found on average each additional month between lucerne removal and wheat sowing led to a yield increase of 8% compared to removal just before sowing.

There was no yield difference in 2012 as a result of the different removal times in spring 2010 or autumn 2011. This is to be expected as the differences created by the two removal times would have dissipated by the second crop. So it would appear there is an effect due to removal time but it only lasts for the first year of the crop rotation.

Oil content of the canola in 2011 decreased by 3% in response to the autumn 2011 lucerne removal compared to the spring 2010 removal (Table 3). These results are supported by similar findings in NSW. In contrast the cereal grain protein increased by 1.1% in wheat and 1.4% in barley with the autumn 2011 removal. This was thought to be a result of lower yield from the autumn removal providing more nitrogen for each unit of grain (less dilution effect).

Table 3. Grain quality for crops in 2011 and 2012.

Crop	Time of lucerne removal	2011			2012			
		Protein (%)	Screenings (%)	Oil (%)	Protein (%)	Screenings (%)	Oil (%)	Test wt (kg/hl)
Canola	Spring 2010	N/A	N/A	38.4	23.3	N/A	37.6	68
	Autumn 2011	N/A	N/A	35.4	23.1	N/A	38.2	67
Wheat	Spring 2010	12.8	5.1	N/A	11.4	2.5	N/A	64
	Autumn 2011	13.9	3.6	N/A	11.8	2.3	N/A	62
Barley	Spring 2010	15.3	2.5	N/A	13.3	8.5	N/A	64
	Autumn 2011	16.7	3.9	N/A	14.5	10.3	N/A	61

The relatively high grain protein in both the wheat and barley, regardless of time of lucerne removal, indicates that soil nitrogen was not limiting at grain fill. There were no differences in grain quality in 2012 for any crop type. This also supports the conclusion that the impact of lucerne removal only affects the first crop.

Explaining the grain yield and quality differences with different lucerne removal times

Soil moisture

Soil moisture probes were installed to a depth of 1.2 m and monitored on a regular basis to determine the impact the time of lucerne removal had on soil water. The spring removal in December 2010 combined with unseasonal summer rainfall, led to a significant accumulation of soil water in the profile when the crops were sown in 2011 (average accumulation under the canola, wheat and barley was 41 mm more on May 19) (Figure 1). This additional soil water was used by the crops in the latter part of the season (Oct to Dec), so the average difference was only 22mm at harvest. This means an extra 19 mm of stored water was used on average by the crops.

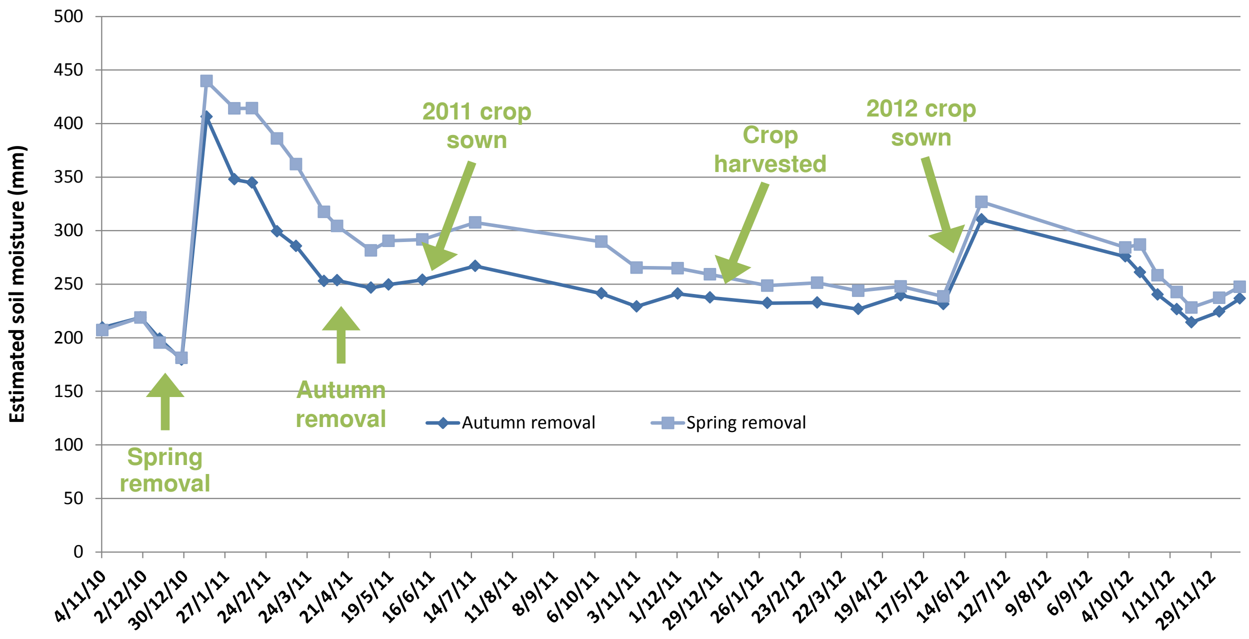

Figure 1. Average soil water under canola, wheat and barley from spring and autumn lucerne removal (0 - 120 cm).

Differences in soil moisture narrowed over the summer of 2011/2012, so by sowing in May 2012, the difference in soil moisture was only 7 mm. Soil moisture extraction under the 2012 crop was similar, as were grain yields. A calculation of the water use efficiency of this 19mm was higher than industry recognised standards.

The difference in accumulated soil moisture from the spring removal may have been greater had the lucerne been completely killed. 38% of lucerne plants survived the initial removal regime. As these surviving plants recovered in late summer they used saved soil moisture from the top 60 cm (Figure 2). All saved moisture from the spring removal in the top 60 cm was used by the middle of March and continued to be used by the recovering lucerne until spraying and sowing in May 2011. This means the Autumn 2011 treatment resulted in accumulation of more soil moisture in the top 60 cm than the Spring removal (by 23 mm on 18/5/2011). This accumulated topsoil moisture remained until after the crop was sown and throughout most of the growing season. It was only used by the crops late in the season.

However because of the large moisture storage below 60 cm under the spring removal treatment, the net affect was more total soil moisture in the top 120 cm. If the 'lost' moisture from the lucerne regrowth had also been preserved, then yield differences may have been even greater.

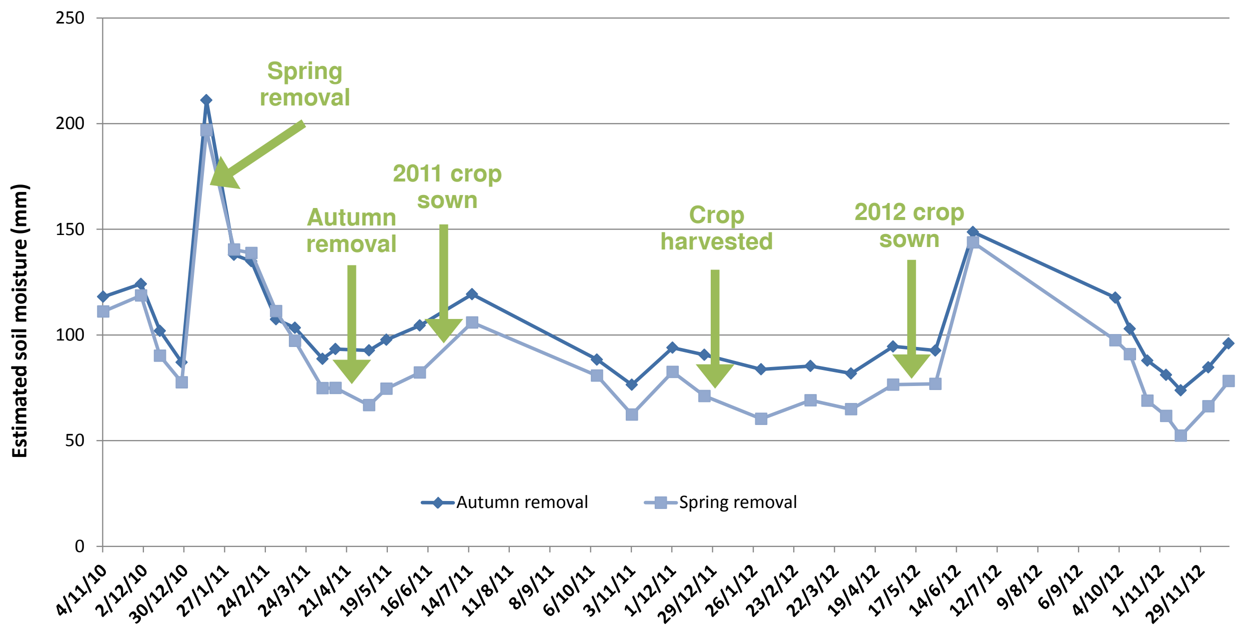

Figure 2. Soil water under Spring and Autumn lucerne removal (0 - 60 cm).

Work on lucerne from other parts of Australia indicates lucerne has the capacity to remove more soil moisture than an annual crop (Figure 3). This potentially creates a greater moisture deficit for winter crops than following an annual cropping program.

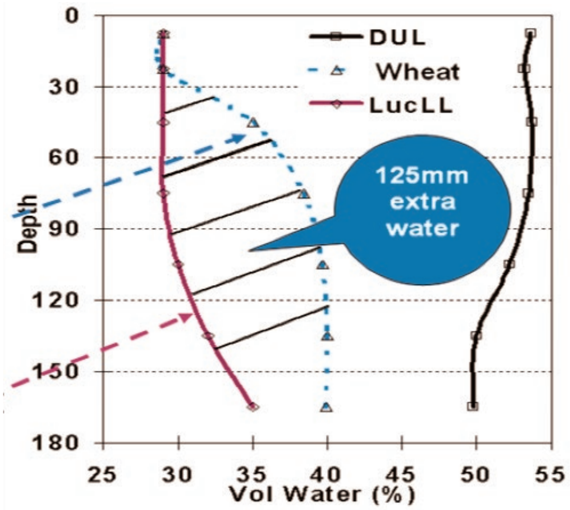

Figure 3. Example of increased soil water deficit created by lucerne on the Jimbour plains (Source: GRDC EFS Project, Dalgliesh et al. Personal correspondence)

Similar results were observed at Inverleigh when comparing the soil moisture under the cropping areas at the time of typical autumn take out compared to an adjacent lucerne area (Figure 4). The soil moisture under the lucerne was much lower, indicating a significant soil water deficit (139 mm) that would need to be replenished.

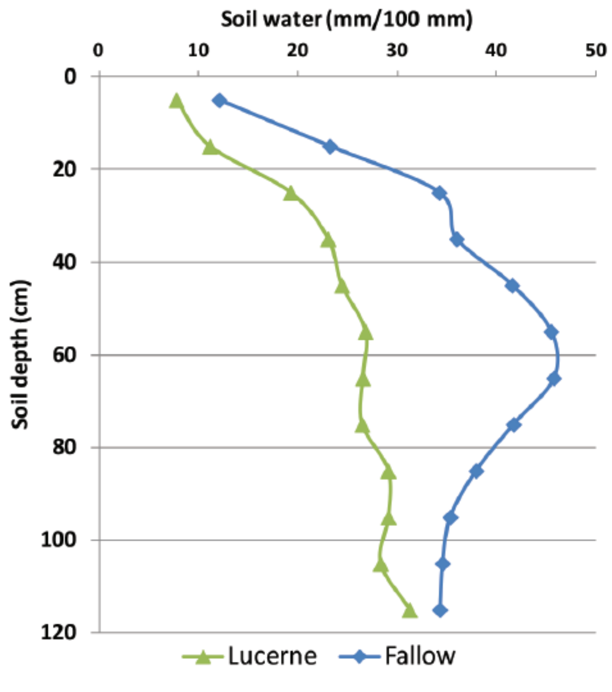

Figure 4. Soil moisture to a depth of 120 cm in mid March (typical time for lucerne removal in autumn) under lucerne or crop fallow.

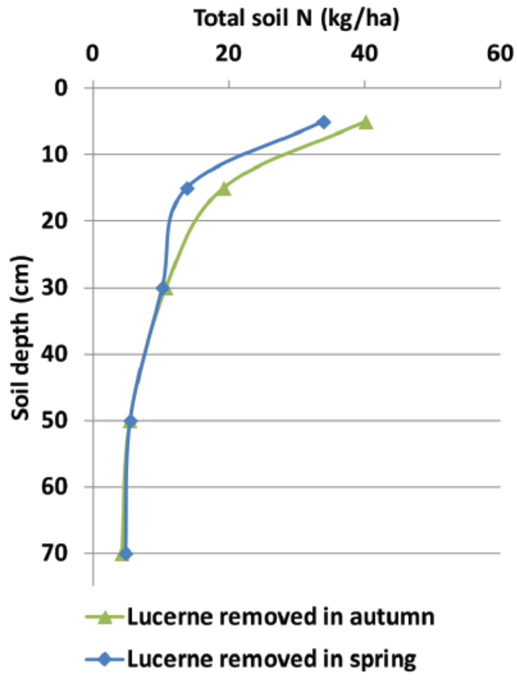

Figure 5. Total soil nitrogen accumulation with autumn and spring removal times (May 2011)

Nitrogen

Soil nitrogen was similar under the spring and autumn removed treatments (Figure 5) when tested in mid May 2011. The spring removed lucerne had 68 kg N/ha when the wheat crop was sown compared to 80 kg N/ha for autumn removed lucerne.

By May 2012 the total soil nitrogen had increased to 105 kg N/ha with the spring removed lucerne and 114 kg N/ha with the autumn removed lucerne. The increase in nitrogen compared to May 2011 was accumulated at depth and not in the topsoil.

A nitrogen budget for the 2011 wheat crop would suggest the spring removal of lucerne supplied marginally more nitrogen to the crop during the growing season than the autumn removed treatment (Table 4). However the greatest benefit was the nitrogen derived from the mineralisation of the organic matter. Large quantities of nitrogen (179 kg N/ha with the spring lucerne removal and 156 kg N/ha from the autumn removed lucerne) were supplied to the crop from lucerne breakdown (mineralisation).

Table 4. Nitrogen budget for wheat grown in 2011.

Treatment	Starting soil nitrogen May 2011 (kg N/ha)	Nitrogen applied to the crop (kg N/ha)[1]	Estimated crop nitrogen removed from grain (kg N/ha)[2]	Measured soil nitrogen May 2012 (kg N/ha)	Nitrogen derived from soil mineralisation[3] (kg N/ha)
Spring removal	68	+10	-152	105	179
Autumn removal	80	+10	-132	114	156

[1] Sown with 100 kg/ha MAP, no in crop nitrogen used
[2] Based on 40 kg N per tonne of grain removed
[3] Contributions to the soil nitrogen may also be supplied by free living nitrogen bacteria.

The ongoing supply of nitrogen is expected to continue in future years. The mineralisation of dead lucerne roots provides a slow release of nitrogen into the soil because it is thought the high amount of carbon in the organic matter compared to nitrogen (the C:N ratio) limits the speed at which the organic matter breaks down and the nitrogen is released. Trials from southern NSW (Angus et al, 2000) found the supply of mineral nitrogen following two years of lucerne was 374 kg N/ha. The mineral nitrogen supplied by the lucerne in this trial over one year is approximately half of this measurement.

Crop establishment

Plant establishment of barley was significantly different between removal times in the first year of crop establishment (2011). Autumn removed lucerne had significantly higher establishment (av 99 pl/m^2) than Spring removed lucerne (av 79 pl/m^2) - (LSDp=0.05 = 18.1 pl/m^2). There was no significant difference in crop establishment between the autumn and spring removal in the second year (2012).

Examination of the soil moisture at the time of sowing in 2011 for the top 10 cm revealed the surviving lucerne from the spring removal had completely drained the soil water whereas the autumn removal still had approximately 40% of the plant water still available. This is thought to have enabled a more even germination. The soil moisture at sowing in 2012 was similar and no establishment differences were observed.

Although the 2011 crop establishment was poorer in the spring removed treatments, the yield was still significantly higher than the autumn removed treatment. This suggests the yield difference may have been greater if the spring removed crop establishment had been similar to the autumn removed crop establishment.

Method of lucerne removal

Established lucerne is notoriously difficult to kill. Unsuccessful removal will result in ongoing soil moisture depletion (as discussed previously) and decreased yields in following crops.

Three trials were conducted over two seasons to examine the effectiveness of different herbicide combinations and cultivation to remove established lucerne. Lucerne survival under the different treatments is listed (table 5).

Only one treatment gave acceptable control of lucerne. This was Grazon extra @ 500ml/ha with Roundup DST @ 1.5 lt/ha. Previous trials show lucerne survival of 10.7 pl/m^2 resulted in a significant loss in crop yield (Table 5). Cultivation alone was ineffective, with the best result achieved by two passes with an offset disc in late December. Results from these trials broadly agree with a number of other trials conducted in northern NSW (Cook & Storrie, 1998, pers comm)

Suggested guidelines on effective herbicide use to remove lucerne

- Herbicide timing is critical. Lucerne plants normally start translocation from the shoots to the roots about three weeks after defoliation.
- Plants need to be actively growing and translocating. Moisture or temperature stress will slow this and plants will respond poorly to herbicide application.
- Allow time after herbicide application for translocation to occur. Do not disturb the plant with defoliation or cultivation for 2-3 wks after herbicide application.

Table 5. Lucerne survival at crop sowing with different removal treatments.

Lucerne survival (%) [NB]	Treatment(s) applied	Time of application	Critical comments
2%	Grazon extra @ 500 ml/ha, Roundup DST @ 1.5 L/ha[4]	Late Oct	Plant back period for canola, wheat & barley of 4 months so only suitable for use in the spring/summer.
31%	Kamba 500 @ 600 ml/ha, Roundup Powermax @ 2.5 L/ha[5] + 2 disc cultivation	Spring (mid Dec, mid Jan)	
32%	Cobber 475 (24D amine) @ 1.8 L/ha, Roundup DST @ 1.5 L/ha[1]	Late Oct	May have improved efficacy if applied in autumn with cultivation
33%	Lontrel (clopyralid) @ 300 ml/ha, Roundup DST @ 1.5 L/ha[1]	Late Oct	May have improved efficacy if applied in autumn with cultivation
36%	Kamba 500 @ 500 ml/ha, Ally @ 7 g/ha, Roundup Powermax @ 2.0 L/ha[2] + 2 disc cultivation	Spring (mid Dec, mid Jan)	
43%	2 disc cultivation only	Spring (mid Dec)	
58%	Kamba 500 @ 600 ml/ha, Roundup Powermax @ 2.5 L/ha[2]	Spring (mid Dec)	
62%	Kamba 500 @ 500 ml/ha, Ally @ 7 g/ha, Roundup Powermax @ 2.0 L/ha[2]	Spring (mid Dec)	
73%	3 disc cultivation only	Summer (mid Jan)	
78%	Kamba 500 @ 500 ml/ha, Ally @ 7 g/ha, Roundup Powermax @ 2.0 L/ha[2] + 1 cultivation	Autumn (start April, start May)	
82%	2 disc cultivation only	Summer (mid Jan)	
83%	1 cultivation only	Autumn (start May)	
89%	Kamba 500 @ 600ml/ha, Roundup Powermax @ 2.5lt/ha[2]	Autumn (start April)	
94%	Kamba 500 @ 600ml/ha, Roundup Powermax @ 2.5lt/ha[2] + 1 cultivation	Autumn (start April, start May)	
98%	Kamba 500 @ 500 ml/ha, Ally @ 7 g/ha, Roundup Powermax @ 2.0 L/ha[2]	Autumn	
99%	1 disc cultivation	Summer (mid Jan)	

[NB] Lucerne survival (%) is compared to no treatment
[4] Liaise @ 1.0 L/ha
[5] Liaise @ 1.5 L/ha, LI 700 @ 300 ml/ha

What is the best crop rotation following lucerne?

This question challenges farmers and advisors. Canola is often chosen as the first crop in the rotation after lucerne removal because it is potentially higher grain value and has greater nitrogen demand than wheat or barley. However our experience would suggest farm yields have often been disappointing. Limited soil moisture is often blamed for lower than expected yields and soil measurement indicate a moisture deficit.

The alternative is to grow a cereal. Barley may be better as it believed to utilise moisture under limiting conditions.

The key observations from the first year crops are:

- Canola performed poorly in the first year following lucerne regardless of time of removal (yield and oil), although the canola following the autumn removal was worse than the spring lucerne removal. Plant establishment was satisfactory for both crops and no significant problems were experienced at harvest. The plants however failed to thrive and we speculate that the root system may not have been able to access the moisture at depth.
- Barley yield following spring removal of lucerne were comparable to barley grown under a continuous cropping regime. Autumn removal resulted in a 1.0 t/ha yield loss suggesting production was limited by soil moisture. Both spring and autumn barley crops had very high grain protein, downgrading them to feed classification with the poorer yielding autumn crop being much higher than spring crop (16.7% protein vs 15.3%). This supports

the view that the barley sown after the autumn removal may have run short of moisture during grain fill.

- Wheat appeared to capture value through both yield and protein. Even the lower yielding autumn crop captured value by achieving a higher protein grade. Regardless of the time of lucerne removal, wheat performed much better than barley and roughly twice as well as canola.

The key observations from the second year crops are:

- Yields from any of the crops were not compromised by the lucerne removal times and were similar to continuous cropping.
- Grain protein of both wheat and barley had fallen by about 2% bringing them back to more normal levels. This dropped the wheat to a lower grade (and price) but failed to lower the barley enough to reach malt specifications.
- The oil status of the canola remained low.

Analysis of the three crops for the first two years of the rotation after lucerne removal shows a dramatic difference in gross income (Table 6). The highest income would be generated with the spring removal of lucerne, with wheat followed by canola (grossing $2475/ha over 2 years). In contrast the poorest gross income was from the autumn removal of lucerne followed by canola then barley at less than one half of the return (gross income $1002/ha over 2 years).

Table 6. Gross income from 2 crops following autumn or spring removal of lucerne.

Crop	Time of lucerne removal	Price[6] ($/t)	2011			2012		
			Grade[7] ($/t)	Yield (t/ha)	Gross value ($/ha)	Grade ($/t)	Yield (t/ha)	Gross value ($/ha)
Canola	Spring 2010	545	-29	1.5	$773	-36	2.6	$1324
	Autumn 2011	545	-38	0.9	$457	-31	2.9	$1490
Wheat	Spring 2010	303	H2	3.8	$1151	APW	3.2	$944
	Autumn 2011	328	H1	3.3	$1,082	H2	3.0	$909
Barley	Spring 2010	237	F1	3.7	$877	F1	2.4	$569
	Autumn 2011	237	F1	2.7	$640	F1	2.3	$545
Barley, canola	Continuous crop[8]	249	GA1	3.4	$847	-24	2.7	$1408

[6] AWB price $/t 29/1/13 delivered Geelong
[7] 1.5% of crop value for every 1% oil deviation from 42%
[8] Adjacent trial continuously cropped with no lucerne history

Caution must be applied in interpreting these results as prices, premiums, discounts, grade spreads and weather events will vary from year to year and therefore will affect the returns. However the fundamentals of the crop responses to soil nitrogen and moisture following a lucerne phase appear to support the suggested crop choice.

Reduction in lucerne production and livestock implications.

Removing lucerne in the spring to accumulate soil moisture and to allow mineralisation to occur resulted in a loss of fodder production. The loss of fodder production with the spring removal compared to the autumn removal was 2.1 t/ha, but would have been greater if the lucerne was removed successfully in spring.

Lucerne production in the 2010/2011 summer was 5.6 t/ha before the autumn spraying and removal in mid March. Spring removal provided a total of 3.5 t/ha, with 2.0 t/ha grown before spring removal and a further 1.5 t/ha after removal (a result of the failure to completely kill the lucerne in spring resulting in some regrowth in late summer). Total dry matter production from the incomplete spring removal was 0.9 t/ha where herbicides and cultivation were used and 2.2 t/ha where only herbicides were used.

Valuing the 'lost' lucerne

Grazfeed modelling was used to determine the value of the retained lucerne associated with the autumn removal of lucerne. The liveweight gains for a prime lamb enterprise were used in the calculation. The value of the 2.1 t/ha of retained lucerne was $289/ha or $138/t.

The summer when these results were measured was unusually wet with 140 mm received in one four day event in January. This would have increased lucerne production but also replenishment of soil moisture. Therefore the returns, and yield differences may be less in more 'normal' year.

[9] Lambs were valued at $1.65/kg LWT and costs deducted for animal health, supplementary feed, crutching and mortalities to arrive at a net value of per ha.