Growing wheat and barley after serradella, does extra nitrogen help?

Adrian Rossi DPIRD, **Lloyd Cripps** Blackboy Hill Farm, **Andrew Blake** DPIRD, **Geoff Anderson** DPIRD

Key messages

Both barley varieties out yielded wheat by approximately 1000kg/ha in all treatments

Barley yields responded to the highest rate of early post emergent nitrogen (75kgN/ha) with wheat yields plateauing at the 50kgN/ha rate

Ryegrass biomass was two to three times higher in wheat than barley, and this may have significantly reduced wheat yield

Aims

Demand for a strong legume in the system to improve rotation diversity has been a high priority for West Australian broadacre growers. Past trials have looked at how serradella can benefit following cereal crops, however most studies have only tested a single crop type/variety, in a single season. In this trial, we examined (in a single season) how locally grown varieties of barley and wheat responded to N fertiliser after serradella (serradella in year one, then two barley and two wheat varieties in year two). This will help to remove the effect of different seasonal conditions across multiple years, and we can compare crop types (and to a lesser extent, varieties) with greater confidence.

This will help to answer the following questions:

- How will the barley and wheat perform side by side after a serradella phase?
- How much N do we need to apply to each crop type after a serradella phase, and which is the most profitable?
- Will there be Imazethapyr residue from April 2017, and will it affect the non-CL® variety?

This is on the back of a renewed interest in barley and the availability of alternative management options in certain pastures species. For example, the hard seeded pink serradella varieties, Margurita and Erica, are tolerant to most Clearfield ‘CL’ chemicals (imidazolinone), so can be grown in rotation with CL crops with minimal risk of damage from herbicide residue. Summer-sowing allow pastures to be sown outside of busy cereal programs, ready to germinate with rains in autumn to provide early growth. Also the ease of conventional harvesting of these pastures, allows growers to bulk up their own seed.

Method

Site details

Table 1. Site summary details for the paddock, including 2017 and 2018, paddock, farm demo and plot trial.

	Location	Yallabatharra, Western Australia
	Soil Type	Brown/grey coarse (moderately non-wetting) top soil, over coarse orange sand (Soil Group of WA - 446)
	Rotation	Traditionally lupins-wheat until 2017
	Rainfall	350mm annual average, 250mm growing season average
	Yield Average	Wheat 1300kg/ha after lupins with ~50kgN/ha applied
2017	**Serradella**	Margurita (peak biomass of 5-8t/ha)
27/02	Seeding	Summer sown serradella 15kg pod/ha
21/04	Spray	100mL/ha Imazethapyr 700
01/12	Harvest	Paddock harvested, 20ha of the paddock was harvested, yielding ~1000kg/ha pod
-	Grazing	Stubbles grazed by sheep, and all summer weed management done with grazing
2018	**Barley, Wheat**	Scope CL Spartacus CL Chief CL Plus Wyalkatchem (Scope CL in rest of the paddock)
30/05	Spray	Glyphosate knockdown
30/05	Seeding	3cm depth, 65kg/ha wheat, 70kg/ha barley, row spacing 25cm
30/05	Fertiliser	90kg/ha (kg/ha = **N**9, **P**11, **K**10, **S**5, **Cu**0.09, **Zn**0.18)
15/06	Fertiliser	N (urea) top-dressed on plot trial
12/07	Spray	750mL/ha Bromoxynil/Bicyclopyrone
02/08	Fertiliser	Urea and Sulphur applied in the paddock only, 50kg/ha kg/ha = **N**19, **S**3)
23/10	Harvest	Trial harvested

Rainfall 2018

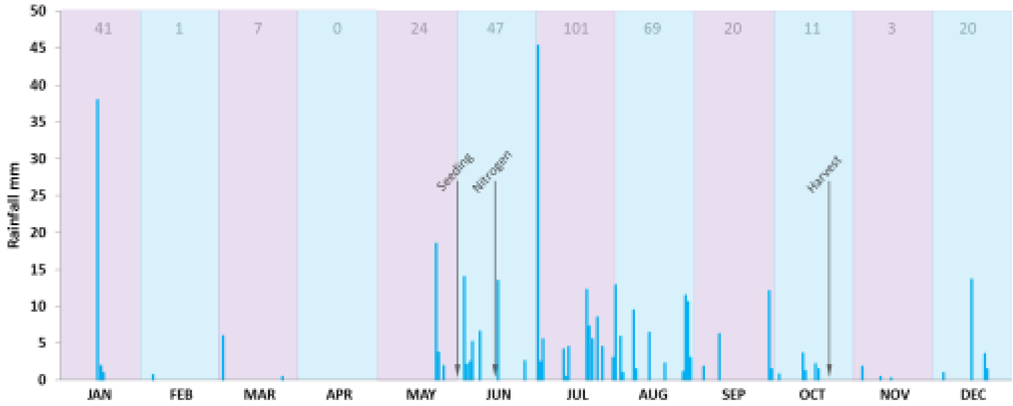

Figure 1. Daily rainfall for 2018 at Yallabatharra (farm rain gauge). Monthly totals (mm) shown at top. Annual total 342mm, growing season total 260mm.

Introduction of serradella 2017

Margurita serradella was summer-sown by the grower in February 2017. Despite a decile one season from February to mid-July, it established very well producing 5-8t/ha dry matter at peak biomass, with an excellent nodulation score of 7-8 (figure 2), using the 0-8 scoring system (Yates et al 2016). About 20 kg of shoot-N on average is fixed for every tonne of herbage dry matter produced for most legume species (Peoples et al 2012). Using 5-8t/ha biomass for the serradella in 2017, it should have produced between 100-160kg/N/ha. The residual organic N fraction can remain in the soil for up to four years (Bowden and Burgess 1993). Under no-till cropping systems, 34% of residual organic N is mineralised over the growing season suggesting 34-54kg/N/ha should have been available for the barley and wheat in 2018.

Commented [JJ1]: What date was this?

Figure 2. Excellent plant structure on the summer-sown serradella at the trial site (photos taken at peak biomass on 4 October 2017).

Imazethapyr 700 at 100mL/ha was applied on 24 April 2017 to control capeweed, doublegees, ryegrass and brome grass. The Imazethapyr controlled most weeds except for a few capeweed and ryegrass, which is common when capeweed and/or ryegrass numbers are dense.

Soil test 2018

Table 2. Soil analysis for the paddock, sampled pre-seeding in early May 2018, with photo showing paddock soil type.

	Ammonium Nitrogen mg/Kg	Nitrate Nitrogen mg/Kg	Phosphorus Colwell mg/Kg	Potassium Colwell mg/Kg	Sulphur mg/Kg	Organic Carbon %	pH $CaCl_2$
0-10cm	8	22	26	54	9.7	0.82	6.4
10-20	< 1	5	10	25	1.7	0.40	5.4
20-30	< 1	2	12	23	1.8	0.26	5.0
30-40	< 1	2	9	18	2.6	0.16	5.0

The soil contained 58kg mineral N/ha in the soil profile to a depth of 40cm with most of this N in the form of nitrate in the 0-10cm soil layer (table 2). This indicates there had been a small amount of mineralisation of N over the summer period compared to amounts observed in other mineralisation studies (Anderson et al 1998a).

Farm demo 2018

Paddock length strips of barley (Scope CL, Spartacus CL) and wheat (Chief CL Plus, Wyalkatchem) (three replicates of each variety) were sown, managed and harvested using farm machinery. Each strip was ~750m long x 9m wide. This paper will focus on the plot trial. Please refer to table 1 for more detail.

Plot trial 2018

Growers had asked if extra N fertiliser would be beneficial for wheat and barley following a serradella pasture. In response to this question, we setup a plot trial across the farm demo with top-dressed urea applied two weeks after seeding to achieve rates of 0, 25, 50 and 75kgN/ha, with three replicates of each rate, across each variety. About 13mm of rain fell two days after the N was applied. All plots were 9m long x 2m wide. Table 1 provides detail of plot trial treatments. A full gross margin was completed with the data.

Results

Yield, gross margin, protein and more

Both barley varieties performed similar, as did both wheats (figures 3 and 4). Barley yields ranged from 2397-3782kg/ha, and wheat from 1305-2334kg/ha (table 3). Barley gross margins ranged from $457-875, and wheat from $207-502 (table 3).

Barley achieved Malt grade for treatments 25N and above, except high screenings limited Scope to Malt 2 (table 3). Although both wheats appeared to achieve APW(N) for 50N and 75N (figure 4), Wyalkatchem was downgraded to AGP due to high screenings (table 3). Screenings for 0N and 25N for Wyalkatchem were under the 5% limit, but protein limited its grade to ASW, this was the same for Chief. Screenings for Chief were low, with good seed size, stable protein across all N rates (table 3).

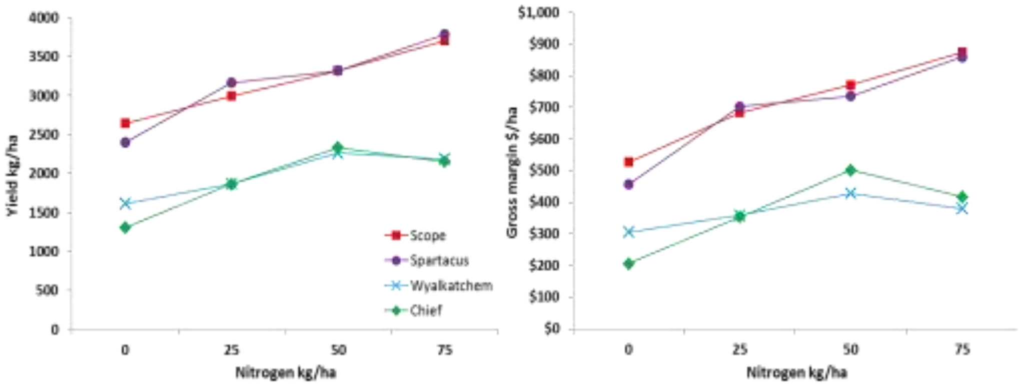

Figure 3. Yields (left) and gross margins (right), of the barley and wheat varieties in the trial. Prices as at 23/10/2018.

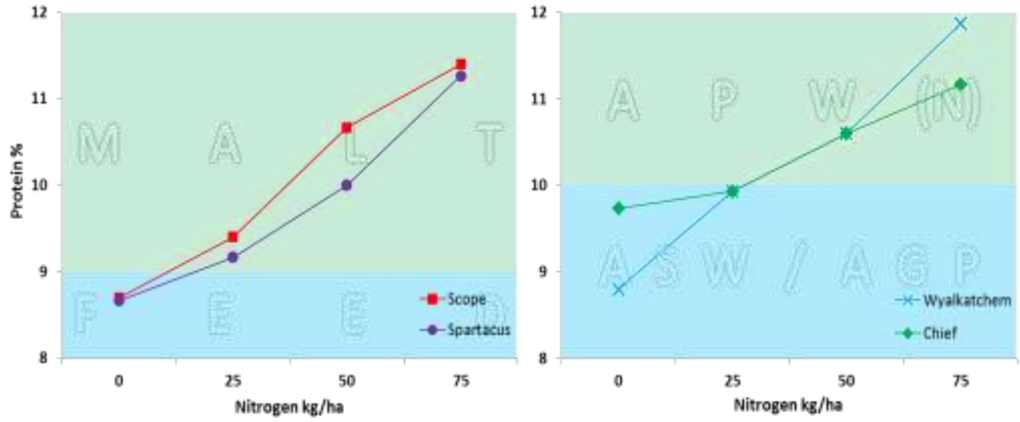

Figure 4. Proteins of the barley (left) and wheat (right) varieties in the trial. Blue indicates the lower grade, and green the higher. Grades as at 23/10/2018

Table 3. Grain quality, grade, yields and gross margins for all treatments (prices and receival standards as at 23/10/2018)

	Nitrogen kg/ha	1000 seed grams	Hectolitre kg/hL	Screenings %	Protein %	Grade	Yield kg/ha	Gross Margin
Scope	**0**	44.2	66.6	24.1	8.7	FEED	2643	$527
	25	43.7	67.9	23.1	9.4	MALT 2	2992	$684
	50	44.9	66.4	20.6	10.7	MALT 2	3319	$771
	75	43.8	66.1	24.1	11.4	MALT 2	3702	$875
Spartacus	**0**	40.5	70.3	16.7	8.7	FEED	2397	$457
	25	41.1	69.2	14.7	9.2	MALT 2	3165	$703
	50	41.7	68.8	18.2	10.0	MALT 1	3319	$736
	75	41.5	70.0	17.4	11.3	MALT 1	3782	$859
Lsd p=0.05					*0.95*		*539*	
Wyalkatchem	**0**	35.5	82.1	3.8	8.8	ASW	1614	$306
	25	36.7	82.4	4.8	9.9	ASW	1868	$359
	50	36.5	82.8	5.4	10.6	AGP	2263	$428
	75	33.8	83.2	8.5	11.9	AGP	2187	$380
Chief	**0**	41.9	81.4	1.5	9.7	ASW	1305	$207
	25	43.6	83.2	2.0	9.9	ASW	1865	$354
	50	42.1	82.5	2.0	10.6	APW(N)	2334	$502
	75	41.7	81.9	2.3	11.2	APW(N)	2153	$418
Lsd p=0.05					*0.63*		*303*	

Weed competition

Ryegrass density in the trial was high, and not controlled well by the herbicides used. Ryegrass in the wheat plots (117 plants/m²) was higher than barley plots (84 plants/m²). Ryegrass in the wheat was much healthier than in the barley, as the barley competed better with the ryegrass. Visual scoring at peak crop biomass suggested at 0N there was twice as much ryegrass biomass in the poorly competitive wheat compared to barley, increasing up to three times as much at 75N.

Conclusion

Answering the questions - How will the barley and wheat perform side by side after a serradella phase?

The barley varieties out yielded wheat by approximately 1000kg/ha in all treatments making barley more profitable than wheat at every N level. Barley often out yields wheat when grown in suitable soils and environments and the pH_{CaCl2} at the site was suitable in the 0-20cm (6.4 down to 5.4), so acidity would not constrain barley yields as can occur on more acidic sandy soils. Despite a lack of summer and autumn rainfall and a 22 May break, the 2018 growing season was excellent. Barley was more effective at competing with ryegrass than wheat. The higher ryegrass biomass in the wheat is likely to have contributed to the lower wheat yields through competition for moisture and nutrients including N.

How much N do we need to apply to each crop type after a serradella phase, and which is the most profitable?

Barley yields responded to the highest rate of early post emergent N (75N) with wheat yields plateauing at 50N despite the crop being on serradella stubble. Favourable seasonal conditions resulted in crops having high yield potentials and high N fertiliser requirements. Economically (and considering risk), for this soil type and environment, 25N and 0N would be practical across most seasons for both crop types, with barley providing a better return. 50N and 75N will have the higher gross margin in well-watered years, but in dry years, it creates too much risk. Barley grazing value would also be greater than wheat.

With a dry summer, autumn, and a late break, the N provided by the serradella to the crop early in the season will be slow, therefore if any extra N is to be added, early is better. Putting a larger amount of N upfront, or an early post-seeding application, will perform best, and should complement the increasing availability of mineralised N from the serradella later in the season (which will help maintain yield and sufficient protein levels). This was outlined by comments from the Grower (in relation to a paddock N application on Scope surrounding the trial), *"an extra application of N (19kgN/ha) was applied in early August as a result of some tissue testing (due to a visually N deficient Scope in June). This is something we normally do not do and the (paddock) result seems to indicate it had little value.*

Our take on it was that we would have been better to up the earlier application (as demonstrated in the trial)". Applying extra N later in the season will increase protein, but have little impact on yield, due to the serradella N becoming highly available in mid-late winter, and this is what was experienced in the trial and Grower paddock application of N. A risk of growing barley following a pasture legume or from applying too much N is high protein levels downgrading the grain from malt to feed. Despite the 2017 serradella pasture and post-emergent N applications, all trial treatments above 0N remained under the upper limit for malt acceptance (12.8% protein).

The capacity of the soil N supply was estimated as; 54kgN/ha from the soil profile measured at seeding + 33kgN/ha from soil organic N over the growing season + 9kgN/ha applied at seeding + 34-54kg/N/ha from the serradella organic N. This gives a potential total N supply of 130-150kgN/ha.

Cereal crops grown in years with minimal N leaching generally have higher N use efficiency than in high leaching years (Anderson et al 1998b). Even with minimal leaching in this trial, N use efficiency would be 45-50% (Fillery 2001). N availability from all sources (soil profile + soil organic mineralisation + seeding application + serradella) for 2018 cereal uptake would be in the range 58-75kgN/ha. The N supply from the soil profile + soil organic mineralisation + seeding application - serradella, is predicted to contribute ~1200kg/ha in cereal yield. The N supply from serradella alone is estimated to contribute ~1100kg/ha. Yield potential for no post-emergent N (0N in this trial) is estimated to be 2300kg/ha, which is close to the observed yields in the barley treatments. The supply of N from the highest rate of post seeding N (75N in this trial) is predicted to contribute ~1500kg/ha (Burgess et al 1991), therefore total yield potential based on the three sources of N would be 3800kg/ha, which is very close to observed yields in the barley treatments for 75N.

All wheat treatments failed to achieve their potential yield based on estimated total N supply. As outlined above, ryegrass biomass was two to three times greater in the wheat than in the barley, and this may be a significant contributor to the lower yields observed in the wheat. It is difficult to estimate N availability for the wheat plots as it is unclear how much N and moisture was intercepted by the ryegrass.

Further considerations for nitrogen from serradella

The serradella in this trial was not grazed, and grazing serradella before flowering may help to start earlier mineralisation of N, and also reduce N immobilisation ('tie-up') by carbon in the serradella stubble (compared to ungrazed serradella) (Kirkegaard et al 2018). Green and brown manuring before serradella pod formation are also excellent options for increasing N for subsequent crops - as N is exported in serradella pods.

Will there still be Imazethapyr residue from 2017, and will it affect the non-CL variety?

The results show there was no significant negative effect of Imazethapyr residue on the Wyalkatchem wheat. The minimum re-crop interval for wheat following application of imazethapyr 700 is 10 months on soils with pH greater than 5.5 ($CaCl_2$) for areas where rainfall between spraying and sowing is expected to be above 300mm. The surface pH at the site was 6.4 and more than 300mm of rainfall was recorded prior to seeding the cereals, so damage from the residue was not expected. Well-managed pH from liming (table 2), summer rain (figure 1), coarse soil type, and possibly high microbial activity supported by the 5-8t/ha biomass of serradella (Holloway et al 2006) would have contributed to the residue breakdown. A pot soil bioassay was performed in March 2018 to check if there was any residual herbicide. The pot test suggested there were residues at concentrations that only affected the tomato plants (highly susceptible) and not the Wyalkatchem (susceptible) and Chief (tolerant).

Key words

Pasture, wheat, barley, nitrogen

Acknowledgments

Thank you to the significant contributions of growers through both trial cooperation and GRDC and R4R investment in DPIRD's Building Crop Protection and Production Agronomy R&D Capacity in regional Western Australia project (also known as the 'Regional Research Agronomy' project). Thank you to the Cripps family and the Northern Agri Group (NAG) for hosting the trial as well as their support and care.

Thank you to Angelo Loi (pasture expertise), Jeremy Lemon (research and project support), Paul Mattingley (economic analysis), Mario D'Antuono (statistical analysis), John Bentley (technical support), and Roger Mandel (herbicide knowledge).

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

® Registered trademark

References

Anderson GC, Fillery IRP, Dolling PJ, Asseng S (1998a) Nitrogen and water flows under pasture-wheat and lupin-wheat rotations in deep sands in Western Australia. 1. Nitrogen fixation in legumes, net mineralisation, and utilisation of soil-derived nitrogen. Australian Journal of Agricultural Research, 49, 329-43.

Anderson GC, Fillery IRP, Dolling PJ, Asseng S (1998b) Nitrogen and water flows under pasture-wheat and lupin-wheat rotations in deep sands in Western Australia. 2. Drainage and nitrate leaching. Australian Journal of Agricultural Research 49, 345-61.

Bowden JW, Burgess S (1993) Estimating soil nitrogen status – ready reckoners. Department of Agriculture, Technote No. 6/93, Perth, Western Australia.

Fillery IRP (2001) The fate of biologically fixed nitrogen in legume-based dryland farming systems: a review. Australian Journal of Experimental Agriculture 41, 361–381

Hollaway KL, Kookana RS, Noy DM, Smith JG, Wilhelm N (2006) Crop damage caused by residual acetolactate synthase herbicides in the soils of south-eastern Australia. Australian Journal of Experimental Agriculture. 46,1323 1331.

Kirkegaard J, Swan T, Hunt J, Vadakattu G, Jones K (2018) The effects of stubble on nitrogen tie-up and supply. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/02/the-effect-of-stubble-on-nitrogen-tie-up-and-supply

Peoples MB, Brockwell J, Hunt JR, Swan AD, Watson L, Hayes RC, Li GD, Hackney B, Nuttall JG, Davies SL, Fillery IRP (2012). Factors affecting the potential contributions of N^2 fixation by legumes in Australian pasture systems. Crop & Pasture Science. 63, 759-786.

Yates RJ, Abaidoo R, Howieson JG (2016) Field experiments with rhizobia. In: Howieson JG, and Dilworth MJ (eds.) Working with rhizobia. Australian Centre for International Agricultural Research, Canberra, 145-166.

GRDC Project Number: DAW00256

Paper reviewed by Jeremy Lemon