The N fixation by a lupin crop may be quite large but it's economic value is small

Andrew Fletcher; **Roger Lawes,** CSIRO Agriculture

Key messages

- Lupins fix large amounts of atmospheric N. However, much of this N is removed in the harvested grain. Thus, there is a smaller residual benefit to the following crop.
- This fixed N should not be considered "free", with an opportunity cost that needs to be considered.
- The benefit of the residual N depends strongly on the use of fertiliser N. As more N is applied to the cereal crop the value of fixed N decreases.
- The economic decision to grow a lupin crop or not should be based around the commodity return from that lupin crop compared with other alternatives, with the residual fixed N being a "bonus".

Background and Aims

Grain legumes have played an important part in Australian agriculture. As part of a rotation they provide both an economic yield and a break in weed/disease cycles. Unlike other break crops they contribute to the N balance of the cropping system via biological N fixation. The amounts of N fixed by crop legumes can be large. For example, the mean measured value of fixed N for a lupin crop was 136 kg N/ha (Unkovich *et al.* 2010). Since their development as a crop in the 1960's and 1970's lupins have played an important part in WA, being well adapted to the prevalent soil and environmental conditions. Lupin areas reached a peak of ~ 1.5 million ha around 2000 (Figure 1). However, since then the area has declined markedly due to a decrease in weed control options, and low lupin prices.

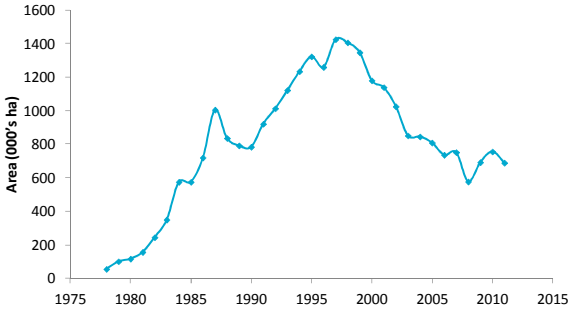

Figure 1 Historical lupin areas across Australia. (Source ABARES)

An understanding of the amount and economic value of N fixed by a lupin crop is required to calculate their value to crop rotations. Atmospheric N fixation has often been treated as a source of "free" N. However, in many cases there is an opportunity cost when growing lupins that needs to be considered. This is the profitability that is foregone for not growing wheat or another crop. Expected lupin yields and price are important determinants of the decision to grow lupins. Typically, historical lupin prices have been comparable to wheat (Figure 2). To break even, lupin yields need to be similar to wheat but typically they are only around 50-60% of wheat. Thus the N benefit needs to be substantial to make up for this opportunity cost. Furthermore, applied N fertiliser may be viewed as an alternative to fixed N and the costs of these two sources needs to be compared.

Our aim in this paper was to undertake a critical evaluation of the economic value of fixed N in a lupin-wheat rotation compared to a continuous wheat-wheat rotation. Our focus was solely on the economic value of fixed N and any opportunity cost from the commodity returns. We did not consider other residual benefits from including lupins in a crop rotation as this would depend strongly on weed/disease pressures.

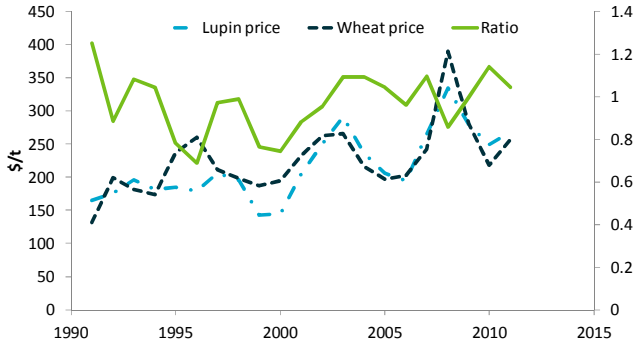

Figure 2 Historical lupin and wheat commodity prices (Source ABARES)

Methods

A desktop analysis was undertaken to evaluate the role of N fixation in the profitability of a lupin–wheat rotation at Dalwallinu. Simulations were made using the APSIM crop simulation model for 100 seasons comparing a wheat-wheat rotation with a lupin-wheat rotation. Simple rainfall based sowing rules were used such that in each situation both wheat and lupin crops were sown at the first possible instance after 15 April. A combination of scenarios was used consisting of high and a low soil N at the beginning of the first crop and four fertiliser N rates (0, 50, 100 and 150 kg N/ha) applied to the wheat.

A simple economic framework was applied to each rotation taking into account both the value of grain from both crops and the amount of fixed N contributed to the cropping system. Economic scenarios included four lupin prices ($200, $250, $300 and $350/t) and five fertiliser N prices ($1.00, $1.50, $2.00, $2.50 and $3.00/kg N) with a fixed wheat price (300$/t). For comparison, mean fertiliser N prices between 2003 and 2013 were $1.24/kg N with a minimum of 79 c/kg N and a maximum of $1.91/kg N (ABARES). The fertiliser N price was used to calculate the cost of fertiliser N applied to the wheat crops but also the extra N contributed to the system from the N fixation of the lupin crop. Data are presented as the difference in profitability between the two rotations over two years.

Our analysis focussed only on the opportunity cost and N benefit to subsequent crops. It was implicitly assumed the production costs for lupins and wheat were identifcal. Furthermore, the analysis assumed that weed and disease pressure did not limit wheat growth. Weed and disease benefits from growing a lupin crop will differ from site to site and important considerations in the decision to grow a break crop, such as lupins. However, they were explicitly not part of this analysis.

Results

Average profit

Under most economic scenarios the wheat-wheat rotation was more profitable than the lupin-wheat rotation (e.g. Table 1). This was because of the opportunity cost for growing lupin due to the low price of lupin grain. As the lupin price was increased the profitability of that rotation increased markedly relative to a wheat-wheat rotation.

The other rotational benefits to wheat from including a lupin crop, such as a break in weed/disease cycles, have not been considered in this analysis. However, we can calculate what these would need to be. For example, the profitability difference between the two rotations with a low soil N, 100 kg N/ha fertiliser N applied a fertiliser price of $1.00/kg and a lupin price of $300/t was $343 in favour of wheat-wheat. At a wheat price of $300/t the additional yield in the second wheat crop, due to the weed/disease break, would need to be 1.1 t/ha. The difference in yield of wheat crop following lupins in WA is on average 0.6 t/ha greater than following wheat (Seymour *et al.* 2012).However, this is an average result and there may be situations where the yield response following lupins is much higher (e.g. high weed or disease pressure).

Table 1 Mean simulated difference (1912-2012) in 2 yearly profit ($) between a lupin-wheat and wheat-wheat rotation at Dalwallinu with a low starting soil N. A value of $0 indicates that the wheat-wheat and lupin-wheat rotations had comparative profitability's.

N fertiliser (kg/ha)	N fertiliser price ($/kg)	Lupin price ($/t) 200	Lupin price ($/t) 250	Lupin price ($/t) 300	Lupin price ($/t) 350
0	1.00	200	268	335	403
0	1.50	219	286	354	421
0	2.00	237	305	372	440
0	2.50	256	323	391	458
0	3.00	275	342	409	477
50	1.00	-314	-247	-179	-112
50	1.50	-278	-210	-143	-76
50	2.00	-241	-174	-107	-39
50	2.50	-205	-138	-70	-3
50	3.00	-169	-101	-34	33
100	1.00	-478	-410	-343	-275
100	1.50	-416	-349	-282	-214
100	2.00	-355	-288	-220	-153
100	2.50	-294	-227	-159	-92
100	3.00	-233	-165	-98	-31
150	1.00	-482	-414	-347	-279
150	1.50	-406	-339	-272	-204
150	2.00	-331	-264	-196	-129
150	2.50	-256	-188	-121	-54
150	3.00	-180	-113	-46	22

Commented [BB1]: So there is a $515 difference due to $50 spent on fertiliser N! That is a bit mind blowing – I would like to see the numbers behind it (yield differences

Commented [fle13p 2]: Not really. It is important to remember that these are comparisons of rotations not absolute profitabilities. This is wheat-wheat vs lupin-wheat. You can't directly compare the response to N fertiliser.

Thus when no N is applied you are growing two N stressed wheat crops in a row. However, in the lupin-wheat rotation the 1st lupin crop will yield more than N stressed wheat and then the subsequent wheat crop is unstressed so it yields more than the 2nd wheat crop.

Added to that is that when you apply fertiliser you need to substract this cost. So at $1/kg you need to substract $100 from the wheat wheat rotation and $50 from the lupin wheat rotation.

Commented [BB3]: Going up the N rates,we have $515, $164 and $4 for each additional 50 kg N/ha. You must be averaging some pretty good yields at Dalwallinu to do this and low N is VERY low N

Year to year variability

The year-to-year variability in profit difference was also explored and largely followed the average values. The higher the mean value of profit difference the more likely the profit was positive. By far the most important determinant of the profitability difference was the rate of fertiliser N applied to the wheat crops (Figure 3). When no fertiliser N was applied to wheat the lupin-wheat rotation was more profitable in approximately 80% of years. However, when fertiliser N was applied the lupin-wheat rotation was less profitable in at least 80% of years. Commodity price, fertiliser N price and soil N level play decreasingly important roles in determining the difference in profitability (data not shown) when fertiliser N is applied to wheat.

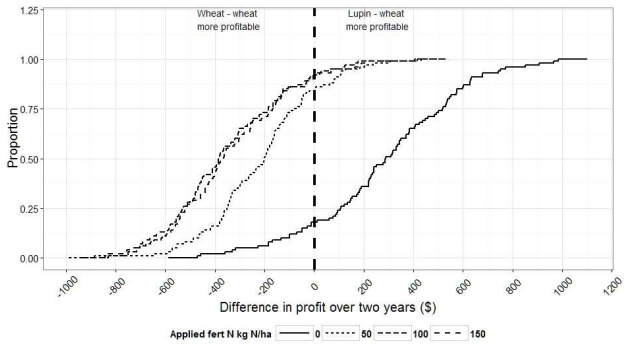

Figure 3. Cumulative distribution of profitability differences between lupin-wheat and wheat-wheat rotations when fertiliser N rate on wheat crops was varied. In this example Lupin price ($250/t), wheat price (300 $/t), soil N (low) and fertiliser N price ($1.50/kg) were held constant. A profit difference of $0 indicates that the rotations had the same profit.

Why is the economic value of fixed N so low in a lupin crop?

There are two main reasons contributing to the low economic value of the fixed N:

1) Much of the N fixed by the lupin crop was removed in the harvested lupin grain. For example in these simulations the mean amount of fixed N in the lupin crops was 113 kg N/ha, however, more than half of this (71 kg N/ha) was removed in the lupin grain and was of no residual value to the following wheat crop.
2) Under current prices fertiliser N was a cheaper alternative source of N. This is highlighted by the results in Table 1. When no fertiliser N was applied, the lupin-wheat rotation was more profitable than the wheat-wheat rotation due to the greater second year wheat yields compared with the wheat-wheat rotation. However, in any scenario where fertiliser N was applied the lupin-wheat rotation was less profitable than the wheat-wheat rotation. This highlighted that the biologically fixed N from the lupin crop was biologically important but that an equivalent amount of fertiliser N could be purchased for less than the opportunity cost of growing the lupin.

Conclusion

In this paper we are neither advocating for or against including lupins in WA crop rotations. If they are profitable (based on yield and commodity price) compared with other alternative crops and provide substantial weed and disease breaks in rotation farmers should continue to include lupins in their rotations. The residual N benefit from Lupins is a minor part of the benefit of Lupin crops. Fertiliser N prices will need to increase substantially before fixed N will become an important part of the economic return from lupins.

Key words

Break crop, Nitrogen, Lupin, Rotation

Acknowledgments

We acknowledge the funding supplied by the GRDC through the project “Reassessing the value and use of fixed nitrogen”

GRDC Project Number: CSA 00037

References

Seymour, M, Kirkegaard, JA, Peoples, MB, White, PF, French, RJ (2012) Break-crop benefits to wheat in Western Australia – insights from over three decades of research. *Crop and Pasture Science* 63, 1-16.

Unkovich, MJ, Baldock, J, Peoples, MB (2010) Prospects and problems of simple linear models for estimating symbiotic N 2 fixation by crop and pasture legumes. *Plant and Soil* 329, 75-89.

Paper reviewed by: Jens Berger