Combined nitrogen inputs from lupin stubble and fertiliser improves wheat productivity on sands

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Key Messages

- Without N fertiliser, wheat following lupins yielded more than double continuous wheat (1.7 vs 3.6 t/ha). A further 27 % yield increase (4.9 t/ha) was achievable when 40 kg N/ha was added to wheat following lupins.
- Increasing N fertiliser inputs on a wheat crop following legumes can improve crop performance and N uptake.
- The mineralisation potential of N in a sandy soil is improved by including lupin in the crop sequence and increased N fertiliser inputs to wheat crops.
- Net N mineralisation over the fallow following lupins can be as high as 32 kg N/ha in a Mallee sandy soil.

Background

Previous research on sandy soils provided evidence of improved productivity by increasing inputs of nitrogen (N) from fertilisers and/or legume residues in the crop sequence. However, questions still remain about the optimal combined management of these for the best productivity gains in wheat. We used a novel approach to better measure the effects of changed fertiliser and stubble type, on the soil supply capacity, as well as crop demand. Trials in 2015 showed that wheat N uptake was responsive to N fertiliser input with legume residues. The difference in soil mineral-N supply at sowing time (0-60 cm) for wheat after lupin vs. continuous wheat was 26 kg N/ha. This was reflected in 26 kg/ha more wheat N uptake following lupin than following wheat at anthesis. The legume-break effect resulted in wheat yields after lupin exceeding 3 t/ha compared to the continuous wheat yield of 1.3 t/ha. We therefore expanded this research in 2016 to better understand the timing of the soil N supply capacity relative to wheat N uptake. This research will help inform management to improve wheat productivity on the sands when using N fertiliser inputs in combination with legume residues.

About the trial

We imposed replicated treatments in sandy soil plots at Karoonda sands combining 3 stubble treatments from the 2015 cropping season: cut and removed (wheat aerial-biomass cut low and removed), wheat, and lupin with 3 N fertiliser rates: nil, medium, and high (0, 20, 40 kg N/ha). Wheat (cv. Scepter) was sown on 2/6/16 at 70 kg/ha. Fertilisers were applied at sowing, banded below the seed and blended as 49 kg/ha of triple superphosphate to supply effective rates of 10 kg P/ha to ensure P was non-limiting, and 43 or 87 kg/ha of urea to supply 20 or 40 kg N/ha respectively. Wheat plants and deep soil samples to 1 m depth were collected at sowing time and at 5 key growth stages to quantify wheat biomass and N uptake, grain yield and soil N supply capacity. Surface soil samples were also collected to analyse for microbial biomass-N, N mineralisation potential and dissolved organic N. Fallow rainfall (Dec 2015-May 2016) was 133 mm, growing season rainfall (May-Nov) was 357 mm (decile 9) and total annual rainfall was 454 mm (decile 9). All plots were harvested on 7/12/16.

Results

Soil mineral-N to 1 m depth at sowing was 32 kg/ha greater after lupin than after wheat as a result of net N mineralisation of legume plant residues occurring over the fallow period (Table 1).

Table 1. *Stubble load, C:N ratio, and N content, and soil mineral-N at sowing (0-1 m depth) under the cut, wheat and lupin stubble treatments. Mean value of 12 replicates with standard deviation in parentheses.*

	Stubble load	Stubble C:N	Stubble biomass N	Soil mineral-N (nitrate+ammonium)
Stubble Treatment	t/ha	ratio	kg/ha	0-1 m, kg/ha
Cut/removed	-----	------	--------	99.5 (10.8) b
Wheat	5.2 (1.5) a	44.7 (8.7) a	46.2 (15.1) a	97.8 (11.0) b
Lupin	1.4 (1.1) b	37.2 (6.5) b	11.5 (10.0) b	129.3 (12.0) a

Stubble load, C:N and biomass in aerial fraction at pre-sowing on 30/5/16. Stubble treatments with different letters indicate significant differences of the mean (bilateral paired t test, $p < 0.05$).

At the wheat seedling stage, the highest soil N mineralisation potential was found for Lupin+40N and remained high over the growing season (Table 2). This is indicative of the benefit of combining legume residues with high N fertiliser application to the overall soil N supply capacity for crops. From tillering onwards, the lowest N mineralisation potential was found under cut/removed stubble treatments. At tillering and anthesis the N mineralisation potential increased ($p < 0.05$) with higher N fertiliser rate (40N > 20N > 0N) regardless of the stubble treatment (data not shown).

Table 2*. Soil N mineralisation potential (0-10 cm depth) at key growth stages. Mean value of 4 replicates with standard deviation in parenthesis. DAS=days after sowing.*

Treatment	Seedling (13DAS)	Tillering (48 DAS)	First node (81 DAS)	Flag leaf (105 DAS)	Anthesis (132 DAS)
Cut+0N	21.9 (4.4) c	17.8 (3.7) f	14.9 (3.9) de	31.2 (8.1) a	26.9 (8.2) de
Cut+20N	14.2 (0.4) c	21.3 (0.9) f	13.9 (2.8) e	23.5 (4.7) a	22.4 (7.0) e
Cut+40N	13.8 (2.4) c	23.5 (4.3) ef	19.9 (3.8) cde	30.8 (6.3) a	30.4 (6.1) de
Wheat+0N	17.1 (3.6) c	26.2 (2.8) de	28.9 (3.7) ab	30.9 (3.5) a	38.7 (9.2) cde
Wheat+20N	29.2 (6.2) b	36.5 (2.1) bc	26.2 (3.7) abc	25.8 (5.5) a	41.0 (7.7) cd
Wheat+40N	20.9 (3.6) c	42.8 (6.8) ab	23.8 (3.4) bc	30.3 (9.3) a	62.9 (13.4) ab
Lupin+0N	23.5 (2.2) c	33.3 (4.7) cd	21.4 (3.6) cd	24.2 (2.7) a	59.3 (13.2) ab
Lupin+20N	18.2 (2.4) c	39.5 (8.9) abc	32.6 (6.8) a	28.3 (2.2) a	49.0 (8.1) bc
Lupin+40N	40.0 (2.6) a	45.2 (5.4) a	26.7 (5.6) abc	31.9 (4.0) a	69.9 (21.8) a

Treatments with different letters within the same column indicate significant differences of the mean for the interaction stubble*N rate using ANVA with split-plot design (LSD Fisher, $p < 0.05$).

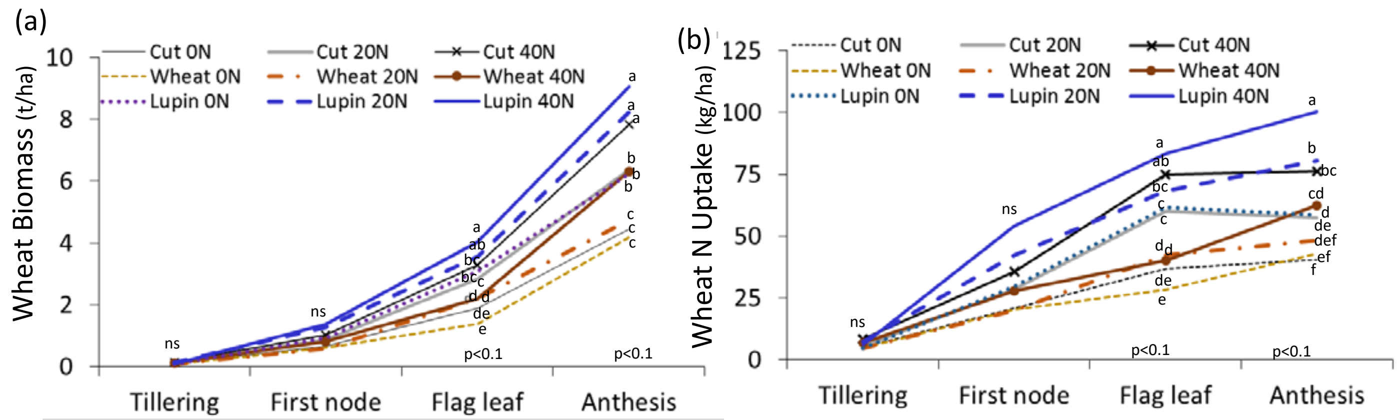
Wheat following lupin stubble was responsive at advanced growth stages to fertiliser N inputs. Plant biomass was about 1.5 fold higher than other N fertilised treatments at flag leaf and anthesis (Fig. 1a) as a result of higher N uptake by wheat (Fig. 1b). Overall more mineral-N was left in the soil after wheat with N fertiliser inputs than after lupins (Fig. 1c) and more N leaching (> 60 cm depth) was observed at advanced stages of wheat after wheat stubble or where it was removed (data not shown). At tillering, the highest soil mineral-N content to 1 m depth was under Lupin+40N with the lowest occurring where wheat stubble was removed (Fig. 1 c). However, at first node and flag leaf stage, soil mineral-N was higher (Fig. 1c), and wheat biomass lower for the wheat and wheat stubble removed treatments (Fig. 1a). Soil profile mineral-N to 1 m tended to decrease more rapidly under wheat after lupin stubble plus fertiliser N inputs (Fig. 1c) as the crop progressed over the season and corresponded with better wheat N uptake in the same treatment (Fig. 1b). Lupin residues combined with N fertiliser inputs were the best performing treatment producing 4.9 t/ha, 1.3 t/ha better than lupin residue with no fertiliser. Wheat yield after Lupin+0N equalled Wheat+40N yield. Also, wheat on stubble removed +20N out yielded Wheat+20N by 0.7 t/ha. The harvest index was highest after lupin residues combined with N fertiliser inputs and after wheat residues at the high N rate (Table 3).

***Table 3.** Grain yield (t/ha), total biomass (straw + grain, t/ha) and harvest index for wheat at harvest. Mean value of 4 replicates with standard deviation in parenthesis.*

Treatment	Grain yield (t/ha)	Total biomass (t/ha)	Harvest index
Cut+0N	2.0 (0.3) de	10.5 (1.4) b	0.2 b
Cut+20N	3.0 (0.5) c	9.7 (2.7) b	0.3 ab
Cut+40N	3.4 (0.4) c	16.8 (2.4) a	0.2 b
Wheat+0N	1.7 (0.4) e	10.9 (3.8) ab	0.2 b
Wheat+20N	2.3 (0.2) d	13.6 (4.0) ab	0.2 b
Wheat+40N	3.4 (0.7) c	8.9 (2.5) b	0.4 a
Lupin+0N	3.6 (1.0) bc	11.3 (3.9) ab	0.3 ab
Lupin+20N	4.5 (0.8) ab	11.5 (3.0) ab	0.5 a
Lupin+40N	4.9 (0.1) a	11.9 (4.5) ab	0.5 a

Treatments with different letters within the same column indicate significant differences of the mean for the interaction stubble*N rate using ANVA with split-plot design (LSD Fisher, $p < 0.05$).

The extra 32 kg/ha of soil N supply for wheat after lupin at sowing time (Table 1) corresponded with 38 kg/ha more N uptake at anthesis by wheat after Lupin+40N compared with Wheat+40N (Fig 1b). Wheat biomass production and N uptake at the end of the season were higher under N fertilised treatments when the wheat stubble was removed (Fig. 1 a, b) compared with wheat stubble retained. This suggests that some net N immobilisation might have occurred under the wheat stubble treatments. It should be noted however, that due to the wet season conditions, wheat plants were affected by diseases (i.e. fusarium, take-all) at grain filling. Such diseases mostly affected wheat stubble treatments regardless of the N rate, with less severity being observed under lupin stubble treatments (wheat > cut > lupin).



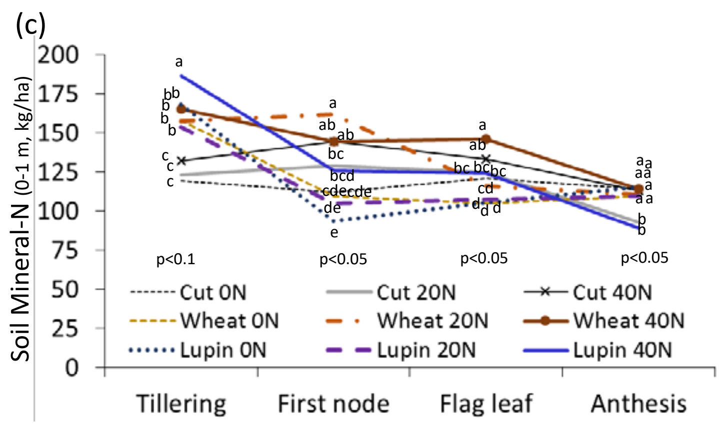


***Figure 1.** Wheat total aerial-biomass (a), N uptake (b), and soil mineral-N to 1 m depth (c) at different growth stages. Treatments with different letters within a growth stage indicate significant differences of the mean for the interaction stubble*N rate (LSD F isher, p level as indicated in the chart).*

These experiments showed that yield gains over and above those from the legume-break crop effect can be achieved using N fertiliser inputs of 20-40 kgN/ha. Further analysis are being performed in all treatments to provide a better assessment of the soil water dynamics and the temporal changes in the soil N supply capacity (microbial biomass-N, mineralisable-N, dissolved organic-N) relative to N uptake to address the key functional drivers of N mineralisation.

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