JULY 2013

NITROGEN FIXATION FACT SHEET

NORTHERN REGION

NITROGEN FIXATION AND N BENEFITS OF CHICKPEAS AND FABA BEANS IN NORTHERN FARMING SYSTEMS

Northern grain growers sowed about 450,000 hectares of chickpeas and 30,000 hectares of faba beans in 2012, resulting in the fixation of about 35,000 tonnes of nitrogen (N) worth $55 million in fertiliser N equivalence.

KEY POINTS

- The scale of N and economic benefits from growing a legume is determined by grain yield, the amount of legume biomass and the C:N ratio of the legume residue.
- Well-grown pulses will fix 80 to 120kg N/ha, increase soil nitrate levels by 30 to 40kg N/ha and boost the grain yield of the following wheat crop by 0.5 to 1.5t/ha.
- Nitrogen fixation of chickpeas and faba beans is enhanced by good agronomy, soil management and inoculation.
- Faba beans are more efficient at fixing N than chickpeas, principally because of their nitrate tolerance.

Inspecting a well-managed crop of chickpeas near Gurley in northern NSW.

Cereal and oilseed crops require nitrogen to supplement the nitrogen (N) mineralised from soil organic matter (humus). This can be obtained from pasture legumes, crop legumes grown in rotation with the other grain or seed crops, or fertilisers and manures (see Figure 2).

Pasture and crop legumes fix N in symbiosis with rhizobia, a soil bacteria. Nitrogen gas (N_2) from the atmosphere is absorbed into small nodules on the legume roots where the rhizobia convert the N_2 into ammonia (NH_3). The ammonia is then converted into organic compounds by the plant and used for growth.

N-rich exudates and residues from the legumes add to the N of the soil, from where it can be used by following non-leguminous crops such as cereals and oilseeds.

Nitrogen fixation activity of legumes is strongly linked to the production of legume biomass and suppressed by soil nitrate.

Nitrogen fixation by legumes has economic and environmental benefits. The economic benefits come from cost savings through reduced inputs of fertiliser N (see Tables 1 and 2). The environmental benefits are primarily from reduced emissions of nitrous oxide, a potent greenhouse gas.

Legumes are also effective break crops in cereal-dominated rotations, disrupting the life cycle of soil-borne and stubble-borne diseases.

Trial results

Major observations have been recorded from more than a decade of chickpea-wheat rotation experiments by New South Wales and Queensland Departments of Primary Industries (Agriculture) researchers in the northern region.

- Wheat following chickpeas out-yielded wheat after wheat by an average of 0.7 tonnes per hectare in NSW trials and by 0.6t/ha in Queensland trials. Wheat grain proteins were increased by an average of one per cent in NSW and 1.4 per cent in Queensland.
- Where water was not limiting, the yield benefit was more than 1.5t/ha.
- Nitrate supply was the major factor in the increased wheat yields. In NSW there was, on average, 35kg more nitrate N/ha in the top 1.2m of soil after chickpeas than after wheat.
- Chickpea yields were, on average, about 85 per cent of unfertilised wheat and about 70 per cent of N fertilised wheat.

Legume trends

Australian farmers began to introduce crop legumes into their farming systems during the 1980s. In the 15 years from 1980 to 1995 the area of crop legumes increased almost ten-fold from 0.25 million hectares to two million hectares.

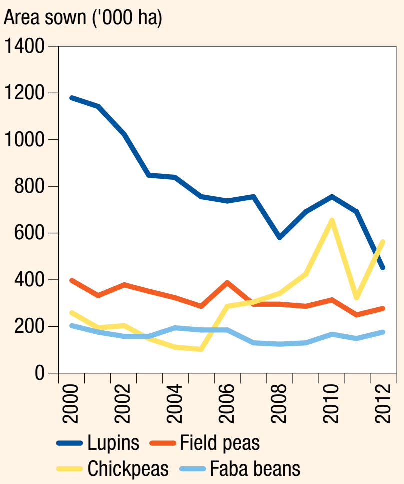
The initial expansion in the early 1980s was almost entirely due to the adoption of lupins in Western Australia, and to some extent to field peas in southern Australia. More recently, the area sown to lupins has fallen dramatically, field pea plantings have stabilised, there has been a modest increase in sowings of lentils and the area of chickpeas has increased sharply.

Chickpeas were the most widely grown crop legume in Australia in 2012 (see Figure 1), with about 80 per cent of the 565,000 hectares total grown in northern NSW and southern and central Queensland.

The increasing popularity of chickpeas in the northern region is not surprising since they are a high-value crop ($400 to $600 per tonne), are well adapted to the neutral to alkaline clay soils typical of the region and have proved their value as a component of northern wheat, barley and sorghum-dominant production systems (see Useful Resources).

About 30,000 hectares of faba beans were also grown in the northern region in 2012.

FIGURE 1 Areas sown in Australia to the major crop legumes – narrow-leafed lupins, peas, chickpeas and faba beans – since 2000.



The rotational benefits of chickpeas on wheat yields essentially lasted for only one season.

The soil nitrate and grain yield benefits of faba beans for a following wheat crop are similar to or slightly higher than those provided by chickpeas. There is evidence that the benefit from faba beans may last longer than that from chickpeas.

Chickpeas and faba beans are both effective break crops, particularly for crown rot of wheat and barley.

N benefit

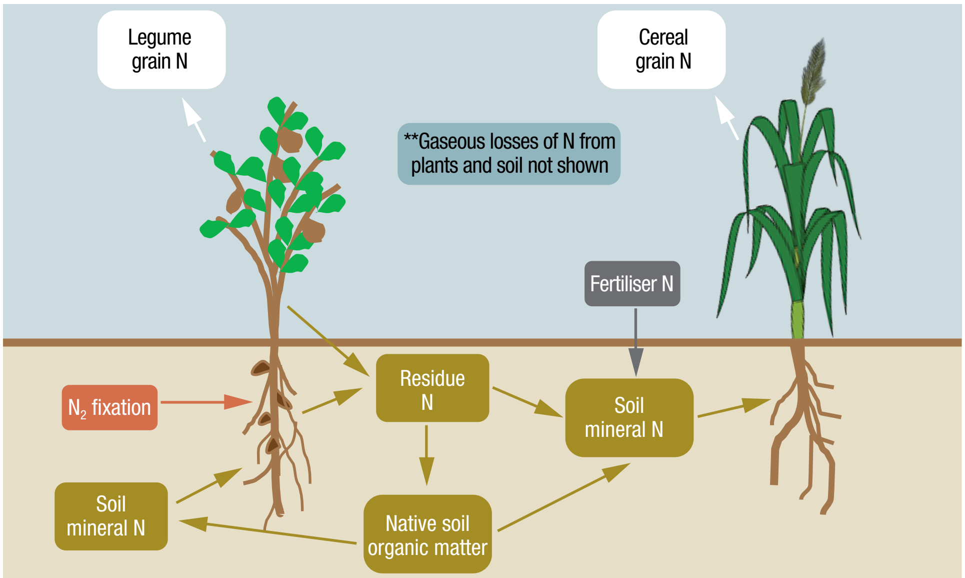
Soil nitrate levels are higher after chickpeas (and faba beans) than after wheat because legumes produce N-rich residues that are readily decomposed by the soil biota to release plant-available mineral N into the soil.

Data for the example in Table 1 were aggregated from two chickpea-wheat rotation experiments conducted by NSW Department of Primary Industries researchers at North Star from 1989 to 1991.

In the first year, chickpeas, unfertilised wheat (wheat 0N) and N fertilised wheat (wheat 100N) were grown in a soil with a moderate level of nitrate at sowing. The chickpeas fixed 135kg N/ha and produced far more residue N (133kg N/ha) than either wheat crop (20 to 55kg N/ha). The chickpea residues were also richer in N, with a C:N ratio of 25:1 compared with C:N ratios of 44:1 (wheat 100N) and 50:1 (wheat 0N) for the wheat residues.

The low C:N ratio of the chickpea residues meant that 16kg mineral (ammonium and nitrate) N/ha was released into the soil during residue decomposition during the summer fallow. The wheat residues immobilised 21 to 22kg mineral N/ha because additional N was needed by the break-down organisms for decomposition to occur.

FIGURE 2 N cycling through a grain legume to the following cereal crop. Gaseous losses of N are not shown, nor are potential leaching losses. All of the flows of N are facilitated by action of the soil biota.



Faba beans in the northern grains region.

TABLE 1 N and yield benefits of a chickpea-wheat rotation compared with unfertilised or N fertilised wheat-wheat. Values are the means of no-tillage and cultivated treatments at two sites in northern NSW.

	Chickpeas – wheat 0N*	Wheat 0N – wheat 0N	Wheat 100N – wheat 0N**
Year 1 (chickpeas or wheat)	Chickpeas	Wheat (0N)	Wheat (100N)
Soil nitrate at sowing (kg N/ha, 1.2 m depth)	67	67	67
Fertiliser N applied (kg N/ha)	0	0	100
Grain yield (t/ha)	2.3	2.3	3.2
Crop N fixed (kg /ha)	135	0	0
Residue N (kg/ha)	133	20	55
Residue C:N	25:1	50:1	44:1
Est. mineralisation or immobilisation (kg N/ha)	+16	-22	-21
Year 2 (wheat only)	Wheat (0N)	Wheat (0N)	Wheat (0N)
Sowing soil nitrate (kg N/ha, 1.2 m depth)	102	53	74
Grain yield (t/ha)	2.8	1.7	1.8

* Wheat 0N = unfertilised wheat ** wheat 100N = N fertilised wheat

TABLE 2 Simple gross margin (GM) analysis of the N and yield benefits of a chickpea-wheat rotation compared with unfertilised or N fertilised wheat-wheat sequences, using yield data from Table 1.

	Chickpeas – wheat 0N*	Wheat 0N – wheat 0N	Wheat 100N – wheat 0N**
Year 1 (chickpeas or wheat)	Chickpeas	Wheat (0N)	Wheat (100N)
Grain yield (t/ha)	2.3	2.3	3.2
Grain ($)[1]	920	575	800
Cost of production ($)[2]	465	270	400
Gross margin ($)	455	305	400
Year 2 (wheat only)	Wheat (0N)	Wheat (0N)	Wheat (0N)
Grain yield (t/ha)	2.8	1.7	1.8
Grain ($)	700	425	450
Cost of production ($)	270	270	270
Gross margin ($)	430	155	180
2-year gross margin ($)	885	460	580

[1] Chickpeas @ $400/t; wheat @$250/t
[2] NSW DPI figures
* Wheat 0N = unfertilised wheat ** wheat 100N = N fertilised wheat

TABLE 3 Effects of tillage on soil water and nitrate at sowing and chickpea and faba bean growth, grain yield and N_2 fixation.

Tillage	Soil (sowing; 1.2m depth)		Shoot		N_2 fixation	
	Water (mm)	Nitrate (kg N/ha)	DM (t/ha)	N (kg/ha)	% crop N from N_2 fixation	Crop N fixed (kg/ha)[B, D]
Chickpeas[A]						
No tillage	144	71	5.4	95	55	107
Cultivated	109	86	4.7	82	44	75
Faba beans[C]						
No tillage	213	88	5.8	126	68	122
Cultivated	175	118	5.5	113	66	107

[A] means of 21 site/years of experiments
[B] Crop N calculated as shoot N x 2
[C] means of 9 site/years of experiments
[D] Crop N calculated as shoot N x 1.4

At the end of the summer fallow, nitrate levels in the soil following chickpeas (102kg N/ha) were much higher than after the unfertilised wheat crop (53kg N/ha) or N-fertilised wheat (74kg N/ha). As a result, grain yields were higher after chickpeas (2.8t/ha) than either of the wheat crops (1.7 and 1.8t/ha).

The data clearly show that the amount and concentration of N in residues (described by the C:N ratios in the example) of the previous crop determine how much plant-available N will be in a cropping soil when the following crop is sown.

Economic benefit

Crop legume-cereal rotations often have better gross margins than cereal-cereal sequences, as illustrated by the gross margin analysis in Table 2.

In Year 1 the gross margins of chickpeas and the N-fertilised wheat were similar. In Year 2, the gross margin for wheat after chickpeas was more than double those of the wheat-wheat sequences.

Over the two years the gross margin of the chickpea-wheat rotation was 50 to 90 per cent greater than those of wheat after wheat, due largely to:

- fertiliser N savings in Year 1;
- improved productivity of the wheat crop following chickpeas due to the extra soil nitrate; and
- the disease-break effect.

Agronomy

Maximising legume productivity by inputs of nutrients such as phosphorus and managing weeds, disease and insects will benefit N_2 fixation.

Good basic agronomy, including a good cover of stubble on the soil surface in the pre-crop fallow, sowing on time and establishing the appropriate plant density, is important for good legume performance.

Legumes must be well nodulated for maximum N_2 fixation and rotational benefits. In most situations farmers will need to inoculate legumes at sowing to ensure good levels of nodulation.

In some circumstances, however, inoculation will have no effect on either nodulation or crop growth because there are adequate numbers of effective rhizobia already in the soil. For guidelines to

TABLE 4 Effects of different levels of sowing soil nitrate on (a) amounts of N fixed by chickpeas and faba beans, and (b) 12-month changes in soil nitrate levels in the paddocks growing chickpeas and faba beans. Values (kg N/ha) were simulated using NBudget, located on the NSW DPI CropMate web site, for 2 t/ha crops growing on clay soil of low-medium fertility in northern NSW.

Soil nitrate-N at sowing	Crop N_2 fixation		Soil nitrate-N benefit	
	Chickpeas	Faba beans	Chickpeas	Faba beans
40	128	114	+57	+53
80	96	105	+17	+29
120	77	102	-11	+12
160	64	97	-27	-5
200	53	94	-40	-21

inoculation of legumes including chickpeas and faba beans, see Rhizobial inoculants Fact Sheet and Inoculating legumes: A practical guide (see Useful Resouces).

Data from NSW Department of Primary Industries long-term rotation experiments in northern NSW show no-till methods improve the productivity and N_2 fixation of chickpeas and faba beans. This is primarily due to increased soil water retention and decreased soil nitrate accumulation during the summer (pre-crop) fallow.

In rotation experiments involving chickpeas, no-tilled soils had 35mm more water available at sowing than cultivated soils and 15kg N/ha less nitrate (see Table 3). The extra soil water resulted in about 16 per cent more growth and the reduced nitrate increased the chickpea crops' dependence on N_2 fixation (55 per cent versus 44 per cent). Total crop N fixed was 43 per cent higher (107kg N/ha) in no-tilled chickpeas than in cultivated chickpeas (75kg N/ha).

Similar results were achieved in trials with faba beans (see Table 3). No-tilled soils contained 38mm more water than cultivated soils at the end of the summer fallows and 30kg N/ha less nitrate. Shoot dry matter, N and crop N fixed were 5 per cent, 12 per cent and 14 per cent respectively higher in no-till crops.

N_2 fixation of chickpeas and faba beans

The N_2 fixation values for chickpeas and faba beans in Table 3 indicate that faba beans fix about 30 per cent more N than chickpeas. This is supported by other experimental and on-farm survey data from the northern grains region and fits well with the notion that faba beans are stronger N_2 fixers than chickpeas.

Data on N_2 fixation by chickpeas and faba beans have been used to construct simple predictive models that have been incorporated into N management decision support tools such as NBudget and Crop Chooser (see Useful Resources).

The impact of different sowing-soil nitrate levels on N_2 fixation of chickpeas and faba beans and the amount of plant-available N in the soil after the legume crops were simulated using NBudget. The data in Table 4 indicate that:

- chickpeas and faba beans fix much the same at soil nitrate levels of 40 to 80kg N/ha, but faba beans are more nitrate tolerant, fixing about 30kg N/ha more than chickpeas at sowing-soil nitrate levels of 120 to 200kg N/ha; and
- because of their high nitrate tolerance, faba beans either increase or at least maintain post-harvest soil nitrate levels at sowing-soil nitrates up to 150kg N/ha. The crossover point for chickpeas is 100kg nitrate-N/ha.

USEFUL RESOURCES

Managing legume and fertiliser N for northern grains cropping. Revised 2013.
Ground Cover Direct: 1800 110 044
www.grdc.com.au/GRDC-Booklet-ManagingFertiliserN

Inoculating legumes: A practical guide
Ground Cover Direct: 1800 110 044
www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

Rhizobial inoculants Fact Sheet: Harvesting the benefits of inoculating legumes
www.grdc.com.au/GRDC-FS-RhizobialInoculants

Choosing rotation crops Fact Sheet: Short-term profits, long-term payback
www.grdc.com.au/GRDC-FS-ChoosingRotationCrops-North
www.grdc.com.au/GRDC-FS-ChoosingBreakCrops-South

Rotations Fact Sheet: Good rotations – when do you need a break?
www.grdc.com.au /GRDC-FS-GoodRotations

MORE INFORMATION

CropMate
http://cropmate.agriculture.nsw.gov.au

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