## Contributions of Fixed Nitrogen by Crop Legumes to Farming Systems of Eastern Australia

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### ABSTRACT

On-farm and experimental measures of the proportion (%Ndfa) and amounts of $N_2$ fixed were collected over 10 years from 84 dryland, cool-season pulse crops (chickpea, faba bean, field pea, lentil, lupin) at eight locations covering a 1200 km north-south transect of eastern Australia from western Victoria to just south of the New South Wales - Queensland border. Estimates of annual (whole plant) amounts of N fixed ranged from 0-341 kg N/ha. The reliance upon $N_2$ fixation for growth was uniformly high in the winter-dominant rainfall areas of Victoria and southern New South Wales (78-89%) and between 20-25 kg shoot N was fixed for every tonne of shoot dry matter (DM) produced. Nitrogen fixation by crops in the summer-dominant rainfall regions of northern New South Wales on the other hand exhibited large variations in %Ndfa (0-81%) and less consistent relationships between $N_2$ fixation and DM accumulation (9-15 kg shoot N fixed/t legume DM). Possible reasons for these observations are discussed.

### KEY WORDS

Pulses, nitrogen fixation, rainfall, soil mineral N.

### INTRODUCTION

Legumes have been widely promoted as desirable components of cropping sequences. The rotational benefits commonly observed following crop legumes may be derived partly from their contribution to 'breaking' cycles of cereal pests and diseases (3). However, the major impact of legumes on the yield of subsequent crops is more often attributed to inputs of symbiotically fixed N during the legume phase and improvements in the availability of soil mineral nitrogen (N) (1,4). However, apart from a few studies (2,5), there is relatively little long-term information on the capacity for crop legumes to fix atmospheric $N_2$ over the range of environments currently farmed in eastern Australia. This paper collates $N_2$ fixation data collected from legume crops over a 10 year period (1989 to 1999) from different locations covering a 1,200 km north-south transect from north-western Victoria (Vic) to near the New South Wales (NSW) - Queensland border. These include farming systems from 'Mediterranean-type' climates (ie. wet winters/dry summers) and regions characterised by summer-dominant rainfall patterns. The information comes from both commercial legume crops and experimental field studies and is utilised to identify the principal factors regulating $N_2$ fixation in these different environments.

### MATERIALS AND METHODS

The crop legumes investigated included chickpea (*Cicer arietinum*), faba bean (*Vicia faba* ), field pea (*Pisum sativum*), lentil (*Lens culinaris*), and narrow-leafed lupin (*Lupinus angustifolius*). Data were collected for 28 different crops in the winter-dominant rainfall regions in the south, from research studies at the Wimmera Research Station at Horsham and from farms in western Vic, from on-farm sites near Rutherglen in north-eastern Vic and Junee in southern NSW, and from research trials near Canberra in the Australian Capital Territory (ACT). Data for 56 crops growing in the summer-dominant rainfall regions of northern NSW came from research studies and commercial pulse crops near Gunnedah, Walgett, Moree, and North Star.

Soils were sampled to at least 90 cm prior to sowing each pulse crop. Soil cores were segmented by depth and analysed for mineral N (nitrate and ammonium) as previously described (8). Measurements of shoot dry matter (DM) were subsequently undertaken during late-grain fill, which was assumed to approximate the time of peak DM and N accumulation. The harvested plant material was dried (70?C), weighed, ground and analysed for total N concentration and $^{15}N$ composition using an automatic N and carbon analyser (ANCA-SL), interfaced with a 20-20 stable isotope mass spectrometer (Europa Scientific, Crewe, UK). The proportion of legume N derived from atmospheric $N_2$ (%Ndfa) and the amount of $N_2$ fixed (kg N/ha) were estimated using the natural $^{15}N$ abundance method as previously described (4,6,8). Non-legume in-crop weeds, and/or neighbouring non-legume crops, which were unfertilised with N, were used as non $N_2$-fixing references. The resulting shoot-based measures of $N_2$ fixation were adjusted to include estimates of fixed N associated with nodulated roots, by assuming that around 33% of the total plant N was partitioned below-ground (published range: 27-40%; 6,7,9). It was also assumed that %Ndfa of nodulated roots was, in each case, identical to that determined for shoots.

## RESULTS AND DISCUSSION

Estimates of the proportion (%Ndfa) and amounts of shoot N fixed at the different locations are presented in Table 1. The data represent measurements collected over several years at most locations. The majority of %Ndfa values were generally high (>60%) and tended to be similar for all legume species in the southern cropping zone. By comparison, both the range (0-81%) and average (19-74%) levels of %Ndfa were far more variable in the northern grain belt (Table 1). The influence of year-to-year fluctuations in growing season rainfall (Fig. 1) and the wide range of concentrations of soil mineral N detected at sowing (Fig. 2) were believed to be major factors contributing to the observed variation.

**Table 1. Estimates of the proportion (%Ndfa) and amounts of shoot N fixed by rainfed pulse crops growing at different locations in eastern Australia.**

| Location | Species | | | $N_2$ fixation | | | |
|---|---|---|---|---|---|---|---|
| and rainfall pattern | the growing seasons studied and number of crops sampled | | | Ndfa (%) | | Amount[a] (kg N $ha^{-1}$ $yr^{-1}$) | |
| | | | | range | mean | range | mean |
| **Winter-dominant** | | | | | | | |
| Horsham - Vic | Faba bean | 1998-99 | 2 | 76-80 | 78 | 123-261 | 192 |
| Horsham - Vic | Lentil | 1998-99 | 9 | 60-90 | 79 | 90-165 | 136 |
| Rutherglen - Vic | Lupin | 1995-97 | 6 | 64-90 | 80 | 87-336 | 220 |
| Horsham - Vic | Field pea | 1995-99 | 5 | 83-92 | 88 | 128-263 | 215 |
| Junee - NSW | Field pea | 1993-97 | 4 | 60-83 | 75 | 198- | 240 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 275 | |
| Canberra - ACT | Field pea | 1999 | 2 | 73-81 | 77 | 72-341 | 206 |
| **Summer-dominant** | | | | | | | |
| Walgett - NSW | Chickpea | 1994-95 | 9 | 2-46 | 19 | 2-68 | 21 |
| Moree - NSW | Chickpea | 1993-95 | 8 | 0-78 | 24 | 0-95 | 29 |
| North Star - NSW | Chickpea | 1989-93 | 7 | 30-79 | 46 | 7-139 | 103 |
| Gunnedah - NSW | Chickpea | 1995-97 | 7 | 35-81 | 53 | 24-162 | 72 |
| Walgett - NSW | Faba bean | 1994-95 | 10 | 22-64 | 46 | 12-78 | 38 |
| Moree - NSW | Faba bean | 1994-95 | 10 | 19-73 | 49 | 18-167 | 85 |
| Gunnedah - NSW | Faba bean | 1995-97 | 5 | 69-79 | 74 | 93-198 | 133 |

[a] Includes an estimate of N contributed by the nodulated roots.

The northern pulse crops experienced large fluctuations in growing season (in-crop) rainfall (including a drought in 1994, Fig. 1) and relied more heavily upon stored water in the rooting zone (which may represent between 46-268 mm to 90 cm depth, 8) than in southern systems. There was some evidence to suggest that rainfall effects on %Ndfa values for legume crops in northern NSW may have been related to growth demand for N (Fig.1).

Because of the variable in-crop rainfall in the summer dominant rainfall regions of northern NSW, fallowing before cropping for the conservation of soil water is a common practice (>85% of pulses may be sown after 6-18 months of fallow). Mineralisation during the fallow period generally resulted in elevated concentrations of soil nitrate (Fig. 2). While soil mineral N appeared to have no influence on shoot DM production, it did have a direct impact on pulse nutrition by suppressing $N_2$ fixation and substituting soil N for fixed N (Fig. 2).

The fact that a number of northern grain growers had sown pulses rather than a cereal or oilseed into soils containing >100 kg nitrate-N $ha^{-1}$ suggests that decisions about when to include a legume in a cropping sequence may have been based on factors such as commodity price, risk diversification or the desire for a cereal disease break rather than concerns about soil N fertility. Farmers in south-eastern Australia on the other hand generally utilise pulses towards the end of a rotation after several cereal and oilseed crops as a means of prolonging the cropping phase before returning to pasture. Consequently the concentrations of soil mineral N tended to be low when sowing leguminous crops (<50 kg N $ha^{-1}$ in the root zone, data not shown) and %Ndfa values for southern crops were usually high (Table 1).

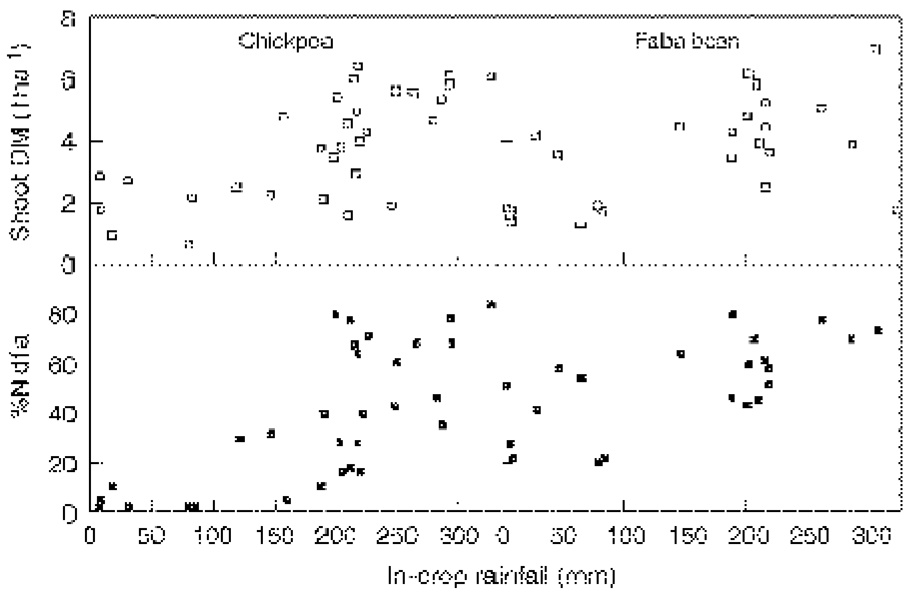


**Figure 1. The effect of in-crop rainfall on the growth (□) and the reliance of dryland chickpea and faba bean crops upon $N_2$ fixation for growth (%Ndfa, ■) in the northern farming systems of eastern Australia.**

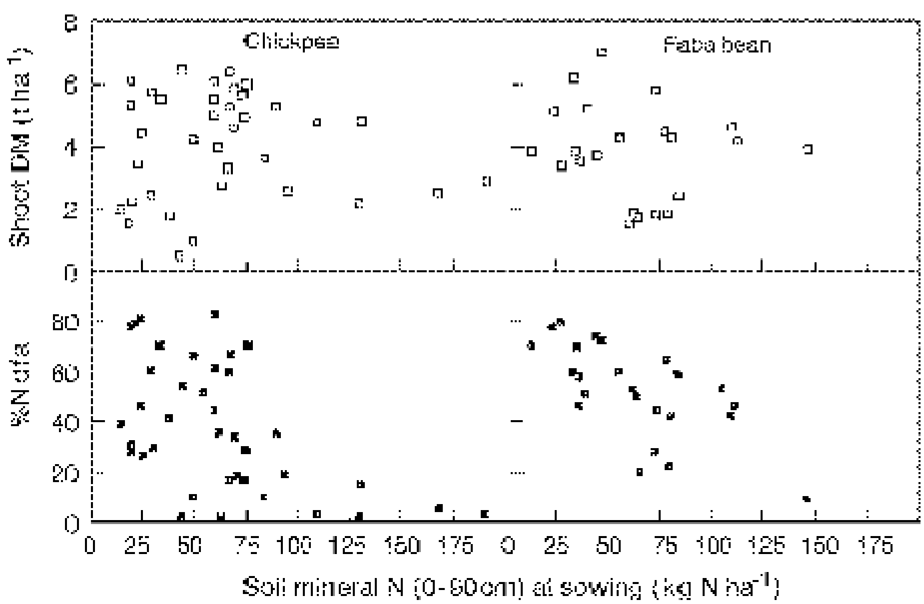


**Figure 2. The effect of the concentration of soil mineral N in the root zone (0-90 cm) at sowing on the growth (□) and the reliance of dryland chickpea and faba bean crops upon $N_2$ fixation for growth (%Ndfa, ■) in the northern farming systems of eastern Australia.**

Since %Ndfa values were consistently high in south-eastern Australia, the amounts of $N_2$ fixed were closely linked to DM accumulation. The legumes fixed on average 20-25 kg shoot N per tonne of legume shoot DM (Fig. 3). By contrast, the amounts of $N_2$ fixed in the cropping systems of northern NSW were more influenced by variations in %Ndfa and there appeared to be only a loose relationship between $N_2$ fixation and biomass production (Fig. 3). Although there was considerable variation in estimates of annual amounts of N fixed at different locations in both regions, the southern crops tended to produce more biomass and fix greater amounts of N than pulses grown in the north (Table 1, Fig. 3). However, it should be noted that data for northern NSW in Table 1 and Figs. 1-3 include information collected during the 1994 drought (14 of the 56 crops), so there may be some downward bias in the results.

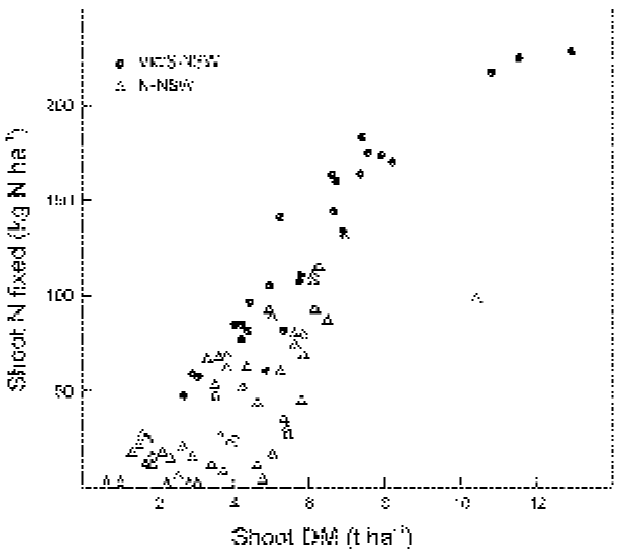


**Figure 3. Relationships between the amounts of shoot N fixed and legume herbage dry matter (DM) production by crop legumes growing in the winter-dominant (●), and summer-dominant (Δ) rainfall regions of eastern Australia.**

## CONCLUSIONS

The data collated from 10 years of measurements of $N_2$ fixation by pulse crops over a wide range of environments indicated large differences in the amounts of N fixed in the farming systems of eastern Australia. Collectively the data have highlighted the key factors regulating the contributions of fixed N, and identified differences in the strategic use of pulses in cropping sequences by grain growers in southern and northern regions. Southern pulse crops tended to follow several years of cereal cropping, concentrations of mineral N at sowing were generally low and legume reliance upon $N_2$ fixation was consistently high. Therefore, the amounts of N fixed were closely linked to biomass production with around 20-25 kg of shoot N being fixed for every tonne of legume shoot DM accumulated. However, in northern NSW variations in %Ndfa had a large impact on amounts of $N_2$ fixed and crops exhibited lower and more variable relationships between $N_2$ fixation and DM (averages of 9-16 kg N t $DM^{-1}$) than observed in the south. This reflected the common use of long fallows to compensate for the more variable in-crop rainfall experienced in the summer dominant rainfall regions of the northern cropping zone and the resulting elevated concentrations of soil mineral N at sowing.

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