NITROGEN BALANCE UNDER LONG TERM ROTATION TRIALS

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A long term rotation trial commenced at the Mallee Research Station in 1980. The aim of the experiment was to determine the relationship between alternative break crops and cereal root disease. The rotations commenced on a paddock which had a high incidence of Take-all. Eleven of the twelve rotations, continuous wheat being the exception, contained at least one break crop. In all rotations, except continuous wheat grasses were sprayed out in June. Break crops included grain legumes, both peas and lupins, medic pastures and oilseed crops. No nitrogenous fertilisers were used. The data, therefore, provides an opportunity to investigate the nitrogen balance of the rotations without confounding the source of mineral nitrogen. All nitrogen would come from three sources - symbiotically fixed nitrogen in the case of legumes, non-symbiotic nitrogen and mineralised soil nitrogen. There were no additions of mineral fertiliser nitrogen.

The nitrogen balance of rotations was calculated from the average nitrogen requirement of the crops based on yield data over the 12 years of the experiment and using best estimates to calculate the nitrogen balance of the legume crops. This provides an indication of the potential of different legumes to meet the demands of the cereal crops and also the sustainability of different rotations.

Figure 1 shows wheat yield response to growing season rainfall (GSR) - measured between April and October. Yield changes would be expected by 1982, that is after a 2 year disease break. 1982 coincided with very low rainfall and the effect of break crops was not expressed until 1983. The data is somewhat limited from the absence of an effective control but it can be seen from the figure that use of GSR is more efficient after 1983, the yield of wheat is more closely aligned with rainfall than prior to 1983.

Average yields are presented in Table 1.

Table 1. Average yields of all crops grown in rotation 1980-91

	Barley	Lupin	Pasture#	Pea	Wheat
Average (t/ha)	2.21	1.01	2.29	1.5	2.5
Dry matter*	4.10	1.52	2.29	2.25	4.64

* Calculated from Harvest Index # 80% medic pasture

Based on these figures it is possible to estimate the nitrogen requirements of crops and estimate the potential of different rotational crops to meet these requirements.

This is assuming average protein content in the wheat - 11.5%, barley - 10.5%, lupins - 30% and peas - 23%. The protein content of stubble is assumed to be 6% for cereals and 10% for legumes. The dry matter of roots is assumed to equal the above ground biomass.

Table 2. Amount of nitrogen required in a growing season

	Barley	Wheat	Pasture	Lupin	Pea
Crop reqt. (kg/N/ha)	116	135	147	97	130

The amount of symbiotic and non-symbiotic nitrogen (kg/N/ha)

Table 3. Amount of symbiotic and non-symbiotic nitrogen (kg/N/ha)

	Barley	Wheat	Pasture	Lupin	Pea
Symb fix *			95	63	84
Non sym fix *	17	17	17	17	17
N requirement (table 2) less additions	99	118	34	17	28

* Source: R.A. Payne & J.N. Ladd, Soil organic matter and nitrogen management in dryland cropping systems, Technical Report No. 211

The first thing to notice is that all crops, over the growing season, rely on the bank of nitrogen in the soil, with the legumes being less reliant because, in the case of grain legumes, of their lower nitrogen requirement and the capacity to fix atmospheric nitrogen.

The amount of nitrogen removed from the system is calculated as follows:

Table 4. Exports of nitrogen for each crop

	Barley	Wheat	Pasture	Lupins	Pea
Grain N	41	46		49	55
Anim resid *	4	4	12	8	8
Anim prod *	1	3	6	3	3
Losses from soil/plant resid *	27	27	42	21	26
Total	-73	-80	-60	-80	-92

* Source: R.A. Payne & J.N. Ladd, Soil organic matter and nitrogen management in dryland cropping systems, Technical Report No. 211

If we add to these the amount of non-symbiotic and symbiotic nitrogen the balance is as follows:

	Barley	Wheat	Pasture	Lupin	Pea
Net N balance (kg/N/ha)	-56	-63	+52	0	+9

Only pastures are in positive balance at the end of the season. On average grain legumes are net users of nitrogen in a season. These are average results from 12 years work. In some years legumes would be significant users of nitrogen (usually the best yielding years), whilst in others they would be net providers.

These figures also allow us to estimate the amount of nitrogen mineralised over a season. Figure 2 indicates that yield and protein have at least been maintained over the 12 years of the trial. This, coupled with the knowledge that the organic nitrogen levels in the soil have remained stable, suggest it is fair to assume that, after the release of nitrogen from the lupin stubbles there is a net zero balance of N preceding a cereal crop. On this basis the nitrogen requirements of the wheat crop, for example, must be met by the mineralisation of soil organic N, that is approximately 50-60 kg/N/ha/y. Under legumes this nitrogen may be considered as having been "spared". Whether the same amounts of nitrogen would be mineralised under legumes as under cereals is still to be decided.

About 40% of the organic nitrogen will become available over the next growing season, for a medic pasture, this will be an additional 21 kg/N/ha.

Losses will occur from this pool, in the Mallee this will be the result, predominantly, of leaching and incorporation into soil biota. On heavier soil types volatilisation losses will increase.

The relative merits of legume pastures compared to grain legumes is one of degree. Medic pastures are more effective suppliers of fixed nitrogen than grain legumes on average.

The actual amount of nitrogen mineralised depends on the C/N ratio in the soil and seasonal factors. Generally Mallee soils have high rates of mineralisation compared to heavier clay soils. For this reason it is very difficult to accumulate organic nitrogen in the soil. The tendency for it is to be mineralised then either utilised by the growing crop or pasture or to be leached below the root zone. Since the amount of available nitrogen is dependant on season it is little wonder that nitrogen utilisation efficiencies are so variable.

On this basis it can be seen that the cereal crop, in such a system relies on the organic nitrogen mineralised over the growing season to meet its needs, with the exception of pasture. The data gives a strong indication that medic dominant pastures are an integral part of sustainable cropping, as they provide a net flow of nitrogen into the soil. Green manuring may also provide a similar effect. Estimates of inputs from the fallow phase are difficult since measurements were intermittent. Any nitrogen accumulation depends heavily on the level of symbiotic fixation from the regenerating medics. Since the plots were fallowed in August, generally prior to the onset of warmer temperatures we can assume that levels of symbiotic N were low. In this case the Net N balance from fallow would be between 0 and 10 kg/N/ha, depending on N losses.

The data can then be analysed according to the effect of the previous crop on yield (Table 5). We should expect that pastures would out-perform all other crops and fallow but this is not the case.

Table 5. Wheat yield following a range of crops. Average of rotations containing relevant crops over 12 years (1980-91)

Previous crop	Average yield (t/ha)
Lupins	2.85
Pasture	2.67
Peas	2.65
Fallow	2.80

In all cases except that of pastures the yield response is in accordance with the magnitude of the nitrogen balance. Peas yielded higher and as a consequence the succeeding wheat crop yielded slightly less. This cannot be explained as a nitrogen effect alone. Yields following lupins were highest despite the fact that a nitrogen balance calculation would suggest there was more available N following a pasture phase. Of particular interest are the results from the fallow where the symbiotic input is zero while losses are also very low, so in effect we get the full benefit from the mineralisation of existing soil N. This would suggest that immobilisation of nitrogen or reduced mineralisation under pastures plays a significant role in nitrogen availability to the succeeding wheat crop.

The data gives no indication of why the wheat after pastures does not yield as high as would be expected. There are problems that are associated with estimates of inputs from stubble and roots. These are more difficult because of the higher levels of non-metabolisable carbon and lower mineralisation potential and difficulties associated with getting reasonable estimates of root biomass in the field. The crops showed no obvious signs of disease so the problem of yield response remains unresolved. The most obvious cause of a reduction in yield would be reduced water availability in Spring, that is the crops are haying off.

The effect of rotation on grain protein levels are shown in Figure 2. The relatively poor performance of peas reflects common experience. It is interesting to note that wheat following fallow exhibits no long term decline in protein levels, whereas wheat after both pasture and lupins has resulted in an increase in protein levels. If the reduced yields are due to haying off then the protein response reflects a decrease in levels of starch deposition, rather than an increase in nitrogen mobilisation from stems and leaves.

This data supports the negative relationship between yield and protein. Producers should note, however that this reflects a high nutrient level, disease free environment. It is easy to accommodate such a relationship if average yields exceed 2.6 t/ha and average protein is 11.0% or more. In situations where fertility is low and/or disease is a problem then the relationship between yield and protein is quite the reverse. To date the discussion of protein in the Mallee has been confounded by the effect of season. Season will always play a major role in determining the protein content of grain in low rainfall areas. A producers aim should be to maximise the opportunities for increased grain protein, by controlling disease and ensuring nitrogen levels are adequate as well as the other agronomic factors which ensure a vigorous and healthy crop.

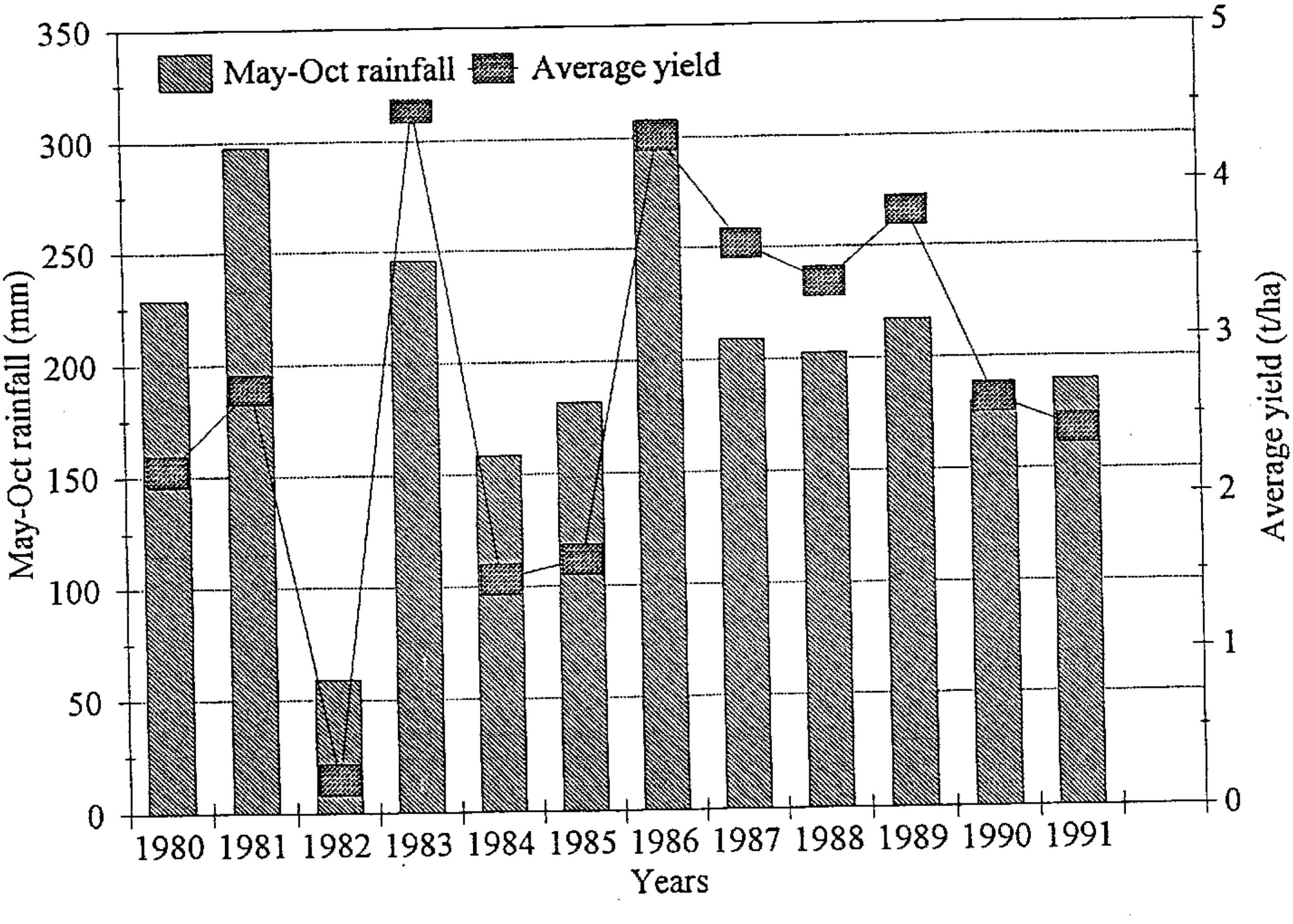

Figure 1. Average wheat yield from all rotations and growing season rainfall (GSR) 1980-91 from long term rotation experiments. Mallee Research Station

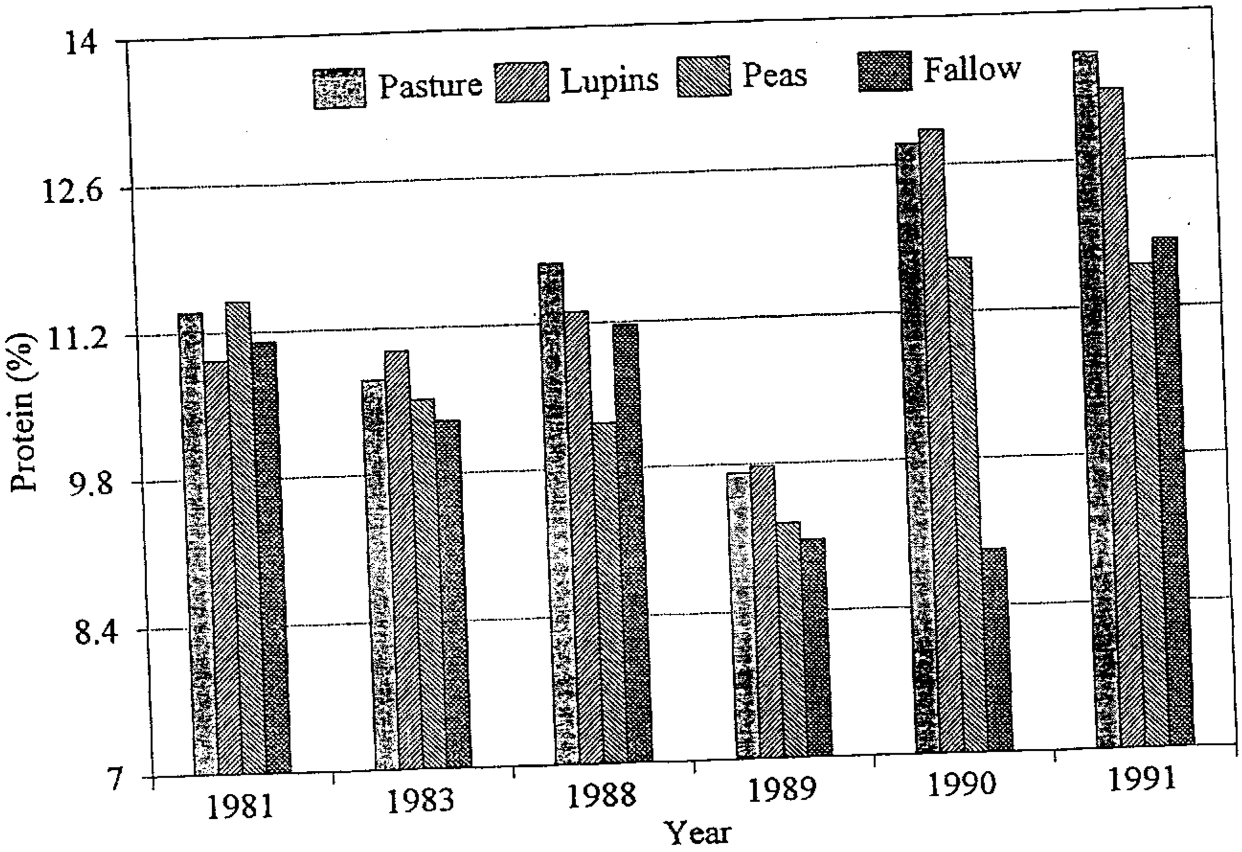

Figure 2. Average protein levels in wheat following different crops from long term rotation trials 1980-91. Mallee Research Station

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REMEMBER: BCDS Field Day - 14 September