Nitrogen Inputs from Pasture Legumes in a Cropping Rotation

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Overview:

- Legume pasture species and management practices have been investigated to determine the most important factors for improving nitrogen inputs to the soil.
- Results have shown significant improvements in the soil available nitrogen after growing pastures with a high proportion (>75%) of legumes.
- The increased soil nitrogen from good stands of pasture legumes is also reflected in the yield and quality of wheat grown the following year.
- A short pasture (2-3 seasons) will provide a significant increase in soil nitrogen and a yield and/or protein response. A long pasture (5 seasons) may not provide more nitrogen than one of 4 seasons.
- No legume species has performed consistently better than any other species.
- Sowing a *mixture* of inoculated pasture legume species that are suited to the region is important to spread the risk and ensure a good stand of legumes is achieved.
- Weed control using grazing management and/or chemical control is seen as the best way to maintain a high level of legumes in the paddock and therefore increase soil nitrogen.

Introduction

Research work at the Condobolin Agricultural Research and Advisory Station is being undertaken to determine the nitrogen contribution from legume pastures in a low-rainfall environment. The research project, jointly funded by NSW Agriculture and GRDC, has been running since 1995. The project aims to improve the understanding of nitrogen transfer from legume pastures and provide practical guidelines which enable farmers to optimise their soil fertility using legumes in the pasture phase and therefore improve the growth of subsequent crops.

It is well known that legume pastures provide nitrogen through a symbiotic relationship with soil bacteria. This relationship enables nitrogen from the atmosphere to be fixed by the plant into a form that is available for plant growth. In the work being conducted at Condobolin, different species and management practices are being investigated to determine the best practices for improving soil nitrogen and crop growth.

Methods

Both field trials and survey work have been used in this project. The trials are located at the Condobolin Agricultural Research and Advisory Station on typical hard-setting red soils. The pasture survey has been conducted on farmers' properties within a 100km radius of Condobolin.

One field trial called the 'Phase' trial will be presented and discussed in this report. This trial investigates the difference between annual and perennial legumes and the length of the pasture phase. Six different pasture treatments were sown on this trial in winter 1995. The pasture treatments included; stands of pure lucerne (Luc); a mixture of annual legume species (Ann), including sub-clover, barrel medic and rose clover; a combination of lucerne and the mixed annual legume species (Luc+Ann); ryegrass and the annual legume species (Rye+Ann); ryegrass and lucerne (Rye+Luc); and ryegrass (Rye) on its own. These pasture treatments were each replicated four times. In the treatments where there were mixtures with ryegrass, the legumes were less than 50 percent of the pasture composition while those treatments without ryegrass had greater than 75 percent legume in the pasture.

Four pasture lengths were investigated. The first pasture length was fallowed in spring 1996 after just 16 months or two seasons of pasture and it was cropped to wheat in winter 1997. The second pasture length was fallowed the following year in spring 1997 after three seasons pasture growth and cropped in 1998. The third pasture phase length was fallowed in spring 1998 and cropped in 1999 with four seasons growth. The fourth and final length representing 5 seasons pasture was fallowed in spring 1999 and was first cropped in 2000. Wheat was also sown in these treatments in each subsequent year.

All pasture treatments were monitored regularly and chemical weed control was used as necessary to keep the species treatments representative. The pastures were crash grazed with sheep after each peak of growth and then left to regenerate. Soil cores were taken to 90cm in each treatment just prior to sowing wheat. The soil was divided into 5 depths; 0-10cm and then each 20cm to 90cm. Each soil depth was analysed for nitrate and ammonium. The wheat was monitored and sampled for dry-matter throughout the season and yield and protein levels were measured.

Results and Discussion

The available soil nitrogen results from the Phase trial are presented in Table 1. These results show the available nitrogen (nitrate and ammonium) values for the combined depths to 90cm from each pasture treatment.

Table 1. Available soil nitrogen (NO_3 + NH_4) to 90cm at sowing following each pasture treatment in each year representing different lengths of pasture in the Phase trial

Available soil N to 90cm (kgN/ha)	**Pasture treatments**					
Year sampled/sown (No. seasons in pasture phase)	**Rye**	**Ann + Rye**	**Luc + Rye**	**Ann**	**Luc**	**Ann + Luc**
1997 (2)	**89**	**88**	**88**	134	**135**	**109**
1998 (3)	**85**	**94**	**95**	122	**107**	136
1999 (4)	**98**	123	**90**	225	**199**	**184**
2000 (5)	**103**	**96**	**128**	**140**	124	137

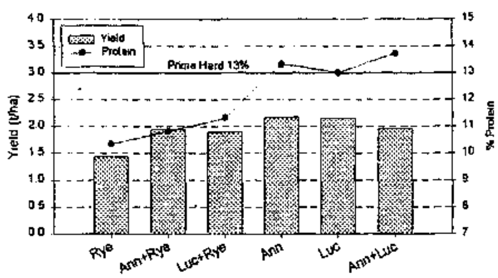
Two interesting things can be observed from these results. Firstly, there is a clear increase in available nitrogen following the three pasture treatments where ryegrass has been excluded from the pasture. And secondly, the effect of each additional year of pasture on available soil nitrogen does not appear to be cumulative.

By comparing the soil nitrogen results from each treatment with the Rye treatment the effect of nitrogen fixation by the legume pasture can be seen. It is clear that in the treatments where ryegrass was included (Ann+Rye, Luc+Rye) the amount of soil nitrogen was not much greater than the Rye treatment. This was because the ryegrass used the nitrogen as it was made available. However, in treatments where the ryegrass was controlled and legumes were dominant (Ann, Luc, Ann+Luc) the available nitrogen was significantly increased compared with the Rye treatment. There was no significant difference between the annual legumes and lucerne in terms of their ability to provide soil nitrogen. This general effect was measured in the first year after pasture each year despite the length of the pasture phase.

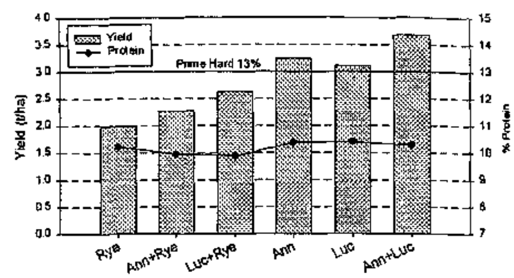
The length of the pasture phase does not seem to have a cumulative effect on the nitrogen that is available. The effect of legumes on the soil nitrogen was similar after both two and three seasons of growth (Table 1). The maximum soil nitrogen was measured after the fourth season of pasture and this decreased again after five seasons to similar levels as after two or three seasons of pasture. Unfortunately, the effect of each phase length was measured in different years, which makes it difficult to separate the pasture length from the climatic conditions for that year. For example, the most available nitrogen was measured in 1999, which was after 4 seasons of pasture. That year also had high temperatures and good summer rainfall compared with other years, which could have increased the amount of soil nitrogen mineralised. Further work needs to be done to interpret this data considering climatic conditions and measuring the potential mineralisation of the soil in each year.

The results of the wheat yield and protein levels from the first crop following each year of these pasture treatments are presented in the graphs in Figure 1. In all years the wheat yields and/or protein contents have significantly increased due to good legume pasture stands. Even after only two seasons of pasture (Figure la) and low seasonal rainfall, the dominant legume pasture treatments (Ann, Luc, Ann+Luc) achieved prime hard status (protein>13%).

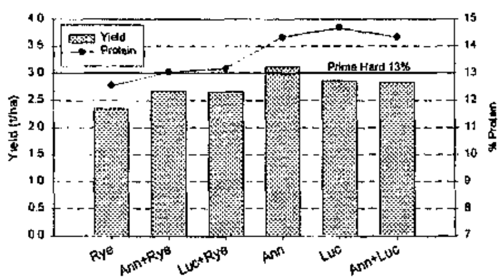
a) First wheat crop 1997 after two seasons of pasture



b) First wheat crop 1998 after three seasons of pasture



c) First wheat crop 1999 after four seasons of pasture



d) First wheat crop 2000 after five seasons of pasture

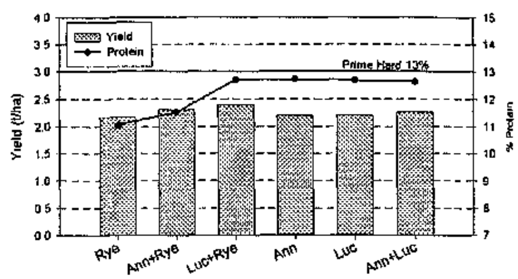


Figure 1. Wheat yield and protein results from the Phase experiment in a) 1997, b) 1998, c) 1999, d) 2000 reflecting the first year of crop following increasing seasons of each pasture treatment. Pasture treatments consist of ryegrass (Rye), lucerne (Luc); a mixture of annual legume species (Ann), including sub-clover, barrel medic and rose clover; and combinations of each of these.

In 1998 (Figure lb) after three seasons of pasture, the response from the legumes was translated into wheat yield rather than protein. This yield response was due to the soft, wet finish that occurred in that year. In treatments where the legumes were dominant in the pasture the wheat yield was increased by as much as 1 to 1.7 t/ha (5 to 8.5 bags/acre) compared with the ryegrass treatment giving yields higher than 3 t/ha (15 bags/acre).

In 1999 (Figure lc), after four seasons of pasture growth, all the treatments containing legume pastures achieved yields above 2.6 t/ha (13 bags/acre) and prime hard protein. This included the legume treatments with ryegrass although the effect was much larger in the pure legume treatments. This year was also a particularly good season with above average rainfall that had a dry finish which is conducive to high yields and proteins.

In 2000 (Figure Id), the response from the legumes was measured after five seasons of pasture. In this year, the pure legume treatments and the Luc+Rye treatment resulted in increased wheat protein although not to 13%. This also reflects the nitrogen status in the soil at the beginning of the season (Table 1). In this year a large amount of wheat in the region was damaged due to untimely rainfall at harvest causing a lot of grain to be 'shot and sprung'. Luckily the wheat in this trial was not badly affected although the protein content was reduced because of this.

Table 2. Grain nitrogen removed (kgN/ha) in first wheat crop following each pasture treatment. The four years represent different lengths of pasture in the Phase trial.

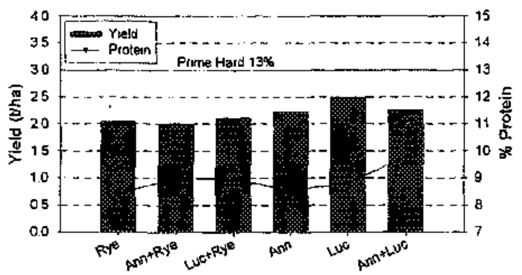
Grain nitrogen removed (kgN/ha)	**Pasture treatments**					
Year harvested (No. seasons in pasture phase)	**Rye**	**Ann + Rye**	**Luc + Rye**	**Ann**	**Luc**	**Ann + Luc**
1997 (2)	**26**	**37**	**38**	**51**	**49**	**47**
1998 (3)	**36**	**40**	**46**	**59**	**57**	**66**
1999 (4)	**52**	**61**	**62**	**78**	**74**	**71**
2000 (5)	**42**	**47**	**53**	**49**	**49**	**50**

The average amount of nitrogen removed in the wheat grain from the first crop each year is presented in Table 2. Grain nitrogen provides a way of combining the yield and protein results together and presents a better way of comparing between years. As can be seen from this data, the grain nitrogen responses from the first wheat crop generally follows the trends seen in the available soil nitrogen data that was measured prior sowing (Table 1).

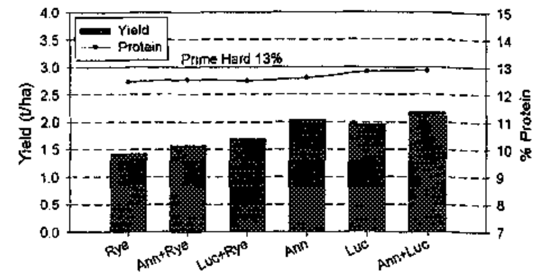
The wheat yield and protein results from the second crop following each of these pasture treatments are presented in the graphs in Figure 2. Generally and as expected, the effects of the pasture treatments seen in the second wheat crop are not as large as they were in the first wheat crop. Despite this, there is still a general trend in the yield and protein data that suggests a better crop performance in the second year after legume pasture treatments compared with the treatments containing only ryegrass.

In 1998, the second crop after two seasons pasture (Figure 2a) shows a slight yield response and no real protein effect with all treatments resulting in protein below 10%. In the second wheat crop after three seasons of pasture in 1999 (Figure 2b) the response from the legume pasture treatments was still evident with increased yield of 0.6 t/ha (3 bags/acre) seen after treatments with good legume content (Ann, Luc and Ann+Luc treatments). The wheat yield in 2000 after four pasture seasons (Figure 2c) remained unchanged by the legume treatments however both the lucerne treatments without ryegrass (Luc and Ann+Luc) gave a small protein response. In the second wheat crop after five pasture seasons (Figure 2d) the response was not as clear although interestingly, the Luc+Rye treatment responded as well as the clean lucerne treatments.

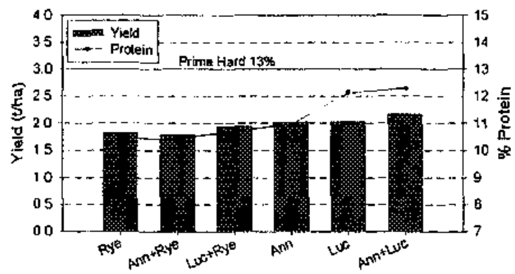
a) Second wheat crop 1998 after two seasons of pasture



b) Second wheat crop 1999 after three seasons of pasture



c) Second wheat crop 2000 after four seasons of pasture



d) Second wheat crop 2001 after five seasons of pasture

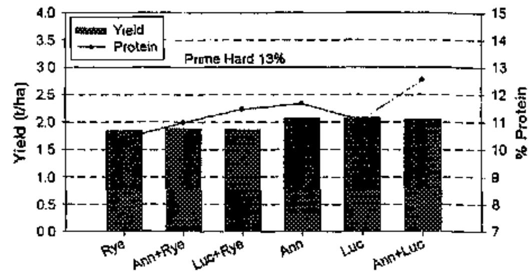


Figure 2. Wheat yield and protein results from the Phase experiment in a) 1998, b) 1999, c) 2000, d) 2001 reflecting the second year of crop following increasing seasons of each pasture treatment. Pasture treatments were the same as in Figure 1.

The amount of nitrogen removed in the wheat grain from the second crop after each treatment is presented in Table 3. As can be seen from this data, the grain nitrogen responses from the second wheat crop still generally follows the trends seen in the available soil nitrogen data that was measured prior to sowing the first crop (Table 1). The overall grain nitrogen response in the second year was greatest in 1999 after four pasture seasons. Interestingly, the longer pasture treatment (five seasons) did not result in higher grain nitrogen removal from the legume treatments as might be expected. Despite this, in all years the treatments containing ryegrass did not perform as well as those with a high proportion of legume.

Table 3. Mean grain nitrogen removed (kgN/ha) from second wheat crop following each pasture treatment in each year representing different lengths of pasture.

Grain nitrogen removed (kgN/ha)	**Pasture treatments**					
Year harvested (No. seasons **in** pasture phase)	**Rye 30**	**Ann + Rye**	**Luc + Rye**	**Ann**	**Luc**	**Ann + Luc**
1997 (2)		**32**	**33**	**34**	**38**	**39**
1998 (3)	**31**	**34**	**37**	**45**	**44**	**49**
1999 (4)	**33**	**34**	**37**	**43**	**43**	**47**
2000 (5)	**34**	**36**	**38**	**42**	**40**	**45**

Results from this trial have shown that significant nitrogen benefits can be achieved from both lucerne and a mix of annual species (barrel medic, subterranean clover and rose clover). All legume species investigated contributed to a yield and /or protein response in the following wheat crop compared with pastures containing significant proportions of ryegrass. No species has consistently performed better than any other. These results highlight the importance of aiming for pastures with a high proportion of legume and keeping grasses and weeds to a minimum.

Conclusion

Pastures with a high proportion of legumes were successful in consistently achieving better wheat yields and/or protein content compared with those with a significant proportion of ryegrass. The effect of the legume pastures on the protein content of wheat varied according to the seasonal conditions experienced. Pasture weeds in general and ryegrass in particular, were found to significantly reduce the yield and quality of the following wheat crop.

Generally, for the best chance of achieving a quality pasture and good wheat returns, sow a *mixture* of inoculated pasture legumes that are suited to the region. Use grazing management and/or chemicals to control weeds and ensure a high proportion of legumes remain in the pasture sward.