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Regenerating pasture legumes in crop rotations

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Summary - Twelve pasture legumes were assessed in the high rainfall region of south-eastern Australia (700 mm average annual rainfall) for their capacities to improve the grain yields of subsequent wheat crops. The ability of these legumes to regenerate following the crop phase was also examined. Pasture-legume dry matter yields in the year proceeding the crop was positively correlated with grain yield, possibly due to higher amounts of nitrogen fixed and improved soil structure. *Trifolium michelianum*, *T. resupinatum*, and *T. subterranean* were considered to be suitable as leys in pasture-crop rotations due to their abilities to regenerate following the crop phase.

Key-words: wheat-pasture rotation, regeneration, *Trifolium* sp., *Melilotus* sp., *Medicago* sp.

Résumé - *La capacité d'amélioration de la production de blé par une rotation avec des légumineuses a été évaluée pour 12 espèces de trèfles dans la région à forte pluviométrie (700 mm de moyenne annuelle) de l'Australie du sud-est. La capacité de régénération après la récolte de la céréale a également été évaluée. La production de phytomasse l'année précédent la céréale est corrélée de façon positive avec le rendement en grain, probablement en raison de la quantité élevée d'azote fixé et de l'amélioration de la structure du sol.* Trifolium michelianum, T. resupinatum *et* T. subterraneum *présentent la meilleure aptitude de régénération après la céréale.*

Mots-clés: *rotation blé/légumineuse, régénération,* Trifolium sp., Melilotus sp., Medicago sp.

Introduction

Agriculture in the high rainfall region of south-eastern Australia has traditionally been based on the wool and meat idustries. The recent downtown in returns from animal products and the advent of crop varieties and management practices more suited to the region have seen an increase in the area of land used for cropping. Currently, cereals and canola are the most commonly sown crops. The susceptibility of pulse legumes to waterlogging, pests and diseases (Gardiner 1999) has resulted in poor adaptation to these environments. The sustainability of crop production systems in this region depends on identifying suitable legumes to aid in weed and disease control and to provide a nitrogen (N) input into the system. Pasture legumes not only have the potential to fulfil this role but also fit in well with existing animal enterprises for integrated grazing and crop farming. An additional benefit of pasture legumes over pulse legumes in crop rotations could be the ability of the pastures to perform in a ley system based on regeneration as opposed to a one-year phase crop. Successful pasture species in such a system would need to have high seed yields and a high degree of hardseededness so that a large proportion of the seedbank remains in the soil during the cropping phase.

The dominant pasture legume in the region at present is *T. subterranean* (subterranean clover). Alternative pasture legumes that may suit the area are being investigated through the National Annual Pasture Legume Improvement Program (NAPLIP). Some of these species may also be adapted to pasture-crop rotations. The aim of this study is to establish the suitability of a range of pasture legumes from NAPLIP for crop rotations in the high rainfall region of south-eastern Australia.

Materials and methods

The experimental site is situated at Hamilton in south-eastern Australia (37° 45′S, 142° 03′E) on a basalt-derived clay loam, pH 4.5 ($CaCl_2$), and an average annual rainfall of 700mm. The climate is cool-temperate with soil moisture deficits in summer, simulating a Mediterranean environment.

Thirty-five pasture legumes from 12 species were hand sown in May 1995 in 2m × 2m plots. They included 7 *Trifolium* species, *T. michelanium* (balansa), *T. subterranean*, *T. resupinatum* (Persian), *T. vesiculosum* (arrowleaf), *T. alexandrium* (berseem), *T. pratense* (red) and *T. xerocephalum*, 3 *Melilotus* species (*M. indica, M. alba and M. officinalis*), 2 *Medicago sativa* species (AWE1 *and cv. Southern Special*) and 2 *Biserrula* species. Seasonal dry matter yields and autumn plant-counts were determined for 3 years (1995-1997). Dry matter yields were determined by cutting plant material from two - 0.25m^2 quadrats per plot. Plant numbers were determined by either counting seedling numbers within two - 0.1m^2 quadrats or from ten - 5cm diameter soil cores per plot, depending on plant numbers. In May 1998, pasture species were chemically removed (using a sulfonyl urea and glyphosate) and a winter wheat crop (Declic) was direct drilled across the whole area. No N fertiliser was applied to the site. Grain yields were determined in January 1999 by cutting two - 0.25m^2 quadrats per plot. Grain was then mechanically threshed.

A row-column design with treatments replicated 4-times was used. Analysis of treatment data was performed using Residual Estimated Maximum Likelihood (REML, Genstat Committee). Transformations to stabilise variance were used where needed ($\log_e$ - 1997 dry matter yields and plant numbers at autumn 1995, 1996 and 1997). Mean values from REML were used for correlations. Contrasts between the species appearing in the highest 10 grain yields were performed using Analysis of Variance. All significant aspects were at the 5% level.

Results and discussion

Mean pasture dry matter yields were 3281 kg/ha (range; 296-8114 kg/ha) in 1995, 3725 kg/ha (range; 1300-8950 kg/ha in 1996 and 1140 kg/ha (range; 10-5517 kg/ha) in 1997. The mean grain yield was 4.6 t/ha (range 2.0 – 7.8 t/ha). The correlation coefficients estimated a significant (P<0.05) positive relationship between pasture-legume dry matter yields in 1997 and 1999 wheat grain yields (Table 1). Higher grain yields could have been the result of higher amounts of N_2 fixed by the different pasture treatments in the previous year. Increased soil N availability following grain or pasture legumes and associated higher cereal grain yields in subsequent crops have been reported in other studies conducted in Australia (Greenland 1971; Evans *et al.* 1991; McNeill 1998). Nitrogen fixation data collected from 540 pastures containing subclover, annual medic, lucerne or white clover growing in a wide range of rainfall zones in eastern Australia showed that, on average, approximately 20-25 kg of shoot N was fixed from the atmosphere, for every tonne of legume dry matter produced, (Peoples *et al.* 1998). Based on this assumption, it is estimated that N_2 fixed from pasture legumes in this study ranged from 0 to 224 kg/ha.

Arrowleaf treatments appeared the most in the top ten grain yield rankings (5/10), with one appearance each from balansa, Persian, subclover, berseem and *M. indica.* Contrasts between species with more than one treatment showed that arrowleaf was the only species with significantly higher grain yields compared to any other species (Table 2).

Table 1 Correlations between wheat grain yields (sown in 1998) and legume pasture dry matter (DM) yields for 1995, 1996 and 1997.

	Pasture DM yield 1995	Pasture DM yield 1996	Pasture DM yield 1997	Wheat grain yield 1999
Pasture DM yield 1995	1.000			
Pasture DM yield 1996	0.495	1.000		
Pasture DM yield 1997	0.787	0.712	1.000	
Wheat grain yield 1999	0.321	0.063	0.361	1.000

Table 2 Contrasts between legume species with respect to grain yields of a subsequent wheat crop. Contrasts only performed on species with more than one treatment.

Contrast	Variance ratio	F probability
Arrowleaf vs Persian	5.68	0.019
Arrowleaf vs *M. Indica*	4.04	0.047
Arrowleaf vs balansa	0.10	0.748
Arrowleaf vs berseem	0.10	0.755
Arrowleaf vs lucerne	0.43	0.512
Arrowleaf vs sub	0.46	0.501
Balansa vs *M. indica*	1.69	0.197
Balansa vs sub	1.06	0.306
Balansa vs berseem	1.01	0.935
Balansa vs lucerne	0.24	0.624
Balansa vs Persian	0.94	0.334
Sub vs *M. indica*	2.49	0.117
Sub vs berseem	0.01	0.940
Sub vs lucerne	0.14	0.708
Sub vs Persian	0.93	0.336

Higher grain yields following arrowleaf clover may have been due to improved soil physical structure. Hard soils during summer months (December-February) can restrict subsequent root penetration of wheat crops. Arrowleaf clovers have deep taproots compared to the other pasture legume species used in this study. Penetration of the soil by these roots in the year proceeding the crop may have opened up the soil, improving the physical structure thus making it possible for the wheat roots to explore further down the soil profile for available nutrients and moisture.

All pasture legumes established well in the first year. In the second year, perennial species including lucerne and red clover had disappeared. By the third season *Melilotus* plant numbers had declined, but plant numbers in certain treatments of balansa, Persian and subterranean clover species had increased considerably (Table 3). Of the original 12 pasture legume species, only these 3 regenerated sufficiently following the crop.

Table 3 Plant regeneration for 35 pasture legume treatments from 12 species showing ability to regenerate following a wheat crop.

Species	Treatment	Plants per m^2 1995	1996	1997	†1999
Arrowleaf	p31884	433	347	150	0
Arrowleaf	tas663	408	132	50	0
Arrowleaf	wa599	495	330	134	0
Arrowleaf	x45752	404	149	184	5
Arrowleaf	Zulu	350	380	484	0
Balansa	krc1	796	825	14883	288
Balansa	krc2	829	1502	13817	253
Balansa	krc3	954	1997	15083	469
Balansa	krc6	996	1436	13017	814
Balansa	Para	212	1320	15167	494
Berseem	Bigbee	529	231	33	0
Berseem	Bisita	529	50	233	5
Biserrula	Bfra56	729	116	333	0
Lucerne	Argyluc	412	0	0	0
Lucerne	Sspcl	287	0	0	0
M. alba	Argy1	600	66	0	0
M. alba	Argy2	583	116	0	0
M. Indica	Mindsp	104	132	0	0
M. Indica	Paum23	500	314	100	3
M. Indica	Shent	333	66	0	5
M. Indica	Steve	254	99	50	0
Melilotus	r99	150	314	0	0
Persian	Kyambro	75	825	8950	73
Persian	Lupers	350	281	117	0
Persian	Maral	591	149	0	8
Persian	p26205	437	380	1000	45
Persian	p45887	608	611	2183	25
Persian	sa18904	662	380	1950	65
Persian	sa20004	171	776	3150	90
Persian	wa411	542	182	167	28
Persian	wa437	579	116	200	125
Red	Astred	370	0	167	3
Sub	Leura	158	1337	6733	60
Sub	Trikkala	100	957	1283	15
Xerocephalum	x14946	787	116	150	0

† Plant numbers following the 1998 wheat crop.

Conclusion

Legume pasture dry matter yields in the year proceeding a wheat crop appeared to influence grain yields. Reasons for such associations may have been higher soil available N and through improved soil structure following the pasture. Balansa, Persian and sub clover species managed to regenerate following the wheat crop suggesting that these species may be suitable as leys in pasture-crop rotations. These species are being further tested in larger plots (10m × 4.5 m) in both 1:1 and 2:1 pasture-crop rotations.

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