LUCERNE IN A WIMMERA FARMING SYSTEM: WATER AND NITROGEN RELATIONS

M.H. McCallum[1], D.J. Connor[2] and G.J. O'Leary[3]

[1]Victorian Institute for Dryland Agriculture
[2]The University of Melbourne. [3]ICRISAT, India

Abstract

Water and nitrogen relations of a lucerne-based farming system (grazed lucerne/annual medic/ryegrass pasture grown in rotation with crops), was compared with continuous cropping (cereal, oilseed and pulse crops) in the Victorian Wimmera. The amount of plant available soil water (0-2 m) after pasture was less than after annual crops (difference of 48 mm), most of which (81%) was extracted at depth (1-2 m). Crop yields (canola, wheat) were not significantly reduced after pasture due to lower residual soil water storage. A wheat simulation study predicted that a small median yield loss of 0.4 t/ha could be expected for the first wheat crop grown after lucerne. In one year (1996), pasture provided a N benefit to a subsequent canola crop equivalent to pre-drilling 46 kg N/ha as fertiliser. Despite some benefits in N fertility, large responses to N fertiliser were still observed in crops (canola, wheat) following pastures; in grain yield, protein and oil yield in canola.

Key words: Lucerne, Wimmera, crop rotation, water, nitrogen.

The long-term threat of dryland salinity, and the decline in soil fertility and grain quality (eg. wheat protein) are major issues concerning farmers in the Victorian Wimmera. Lucerne (Medicago sativa L.) is a drought-hardy perennial legume, which produces high quality forage. Consequently, the inclusion of a lucerne pasture phase into crop rotations in the Wimmera has been suggested as a method of: (i) increasing the water use of farming systems to minimise the development of dryland salinity; and (ii) increasing the soil nitrogen (N) supply to subsequent crops, thus improving both crop yield and quality within the region (2). Whilst the use of lucerne can be beneficial in terms of controlling salinity, the yields of crops (wheat, canola) directly following lucerne may be reduced because less residual soil water is available for crop growth (1,7). Firstly, this paper examines the depth and extent to which lucerne extracts residual soil water, and the possible consequences for following crops. Secondly, the potential N benefits of including lucerne into a crop rotation were investigated. ?Such information exists for the northern cropping-belt of Australia (3, 7), but lucerne/crop rotations have not been extensively evaluated in southern cropping zones, including the Wimmera (4).

Table 1. Treatments of experiment used in the study.

Year	91	92	93	94	95	96	Treatment
Crop/Pasture sequence	B	FB	W	FP	W±N[A]	C±N[A]	1
	B	FB	FP	W	FP	W±N[A]	2
	B/L	P	P	P	C±N[A]	W±N[A]	3
	B/L	P	P	P	P	C±N[A]	4
	B	FB/L	P	P	P	P	5

[A] plots split for N fertiliser 46 kg N ha^{-1} pre-drilled before sowing
B=Barley, B/L=Barley undersown with lucerne, FB=Faba bean, P=Pasture, FB/L=Faba bean undersown with lucerne, W=Wheat, FP=Field pea, C=Canola

Materials and methods

In 1991, an experiment was established to investigate the effect of lucerne on the hydrology and N economy of crop rotations. The experiment compared continuous cropping (cereal, pulse and oilseed crop sequences) with systems involving 3 to 4 years of lucerne-based pasture (including annual medic and Wimmera ryegrass) grown in rotation with a cropping phase. The site was located at the Wimmera Research Station, Dooen (36°40' 39.0'' S., 142°17' 56.6'' E. elev. 151 m) where the long-term average rainfall is 423 mm and the growing season rainfall (April to October) is 293 mm. Soil type was a chromic vertisol (grey cracking clay, Ug5.2). The experiment was a randomised complete block design (3 replications) and plot size was 1 ha. Lucerne was established by undersowing (2 kg/ha) with either barley or faba bean as a cover crop, resulting in a density of 8-26 plants/m^2. In the first year after establishment, annual medic (cv. Parragio, 10 kg/ha) and Wimmera ryegrass (3 kg/ha) were sown into the lucerne pastures, and grazing of the pastures commenced in this year under a rotational system between treatments (1-2 weeks on, 6-7 weeks off). Pastures were winter-cleaned with a grass-selective herbicide (either Fusion?, Verdict 104?, or Select?) in the year prior to entering the cropping phase. Lucerne was removed by tillage in February-March before cropping in May-July. The treatments from the experiment used in this study are outlined in Table 1, and this paper presents results from 1994-96. Soil cores (0-2 m) were taken prior to sowing (16 May 1995 and 17 May 1996) to determine the amount of plant available soil water (PASW) and soil mineral N (SMN) under different treatments (1, 2, 3, 4, 5). Seed material for all crops in 1994-96 were sampled at maturity (December) for grain yield and quality (protein, oil). Simulation modelling, using a wheat model (5), was employed to predict the effect of water use by lucerne on crop production over many years of the typically variable environmental conditions of the region.

Table 2. The amount of plant available soil water (PASW) remaining in the profile following annual crops and lucerne-based pasture.

PASW	0-2 m		0-1 m		1-2 m	
(mm)	95	96	95	96	95	96
Av. crop[A]	119	114	49	38	70	76
Av. pasture[B]	75	63	42	27	32	37
l.s.d (0.10)	*32*	*38*	*18*	*18*	*27*	*23*

[A] 1995 and 1996 (treatment 1 and 2)
[B] 1995 (treatment 3, 4 and 5); 1996 (treatment 4 and 5)

Table 3. The amount of soil mineral N from 0-1 m in the soil profile following various crop and pasture treatments.

Previous crop/pasture in 1994	SMN (kg/ha) 1995	Previous crop/pasture in 1995	SMN (kg/ha) 1996
Field pea (1)[A]	45	Wheat (1)	21
Wheat (2)	91	Field pea (2)	101
Pasture (3)	51	Canola (3)	34
Pasture (4)	62	Pasture (4)	66
Pasture (5)	65	Pasture (5)	24
l.s.d (0.05)	*22*		*24*

[A] number in parenthesis indicates the treatment from Table 1.

Table 4. Grain yield, oil yield and protein content of canola grown after pasture in 1995, and pasture and wheat in 1996. Grain yield and protein content of wheat grown as the second crop after pasture and after field pea in 1996.

Treatment 1995	Grain yield (t/ha)	Protein (%)	Oil yield (kg/ha)	Treatment 1996	Grain yield (t/ha)	Protein (%)	Oil yield (kg/ha)	Treatment 1996	Grain yield (t/ha)	Protein (%)
Canola (3)[A] (-N)	2.13	15.8	969	Canola (1) (-N)	0.41[C]	16.6	176	Wheat (2) (-N)	5.04	9.8
Canola (3) (+N)	2.68	18.1	1174	Canola (1) (+N)	1.02[C]	16.7	443	Wheat (2) (+N)	5.49	9.9
				Canola (4) (-N)	1.02[C]	18.9	417	Wheat (3) (-N)	4.09	6.9
				Canola (4) (+N)	1.35[C]	19.6	541	Wheat (3) (+N)	5.09	8.2
l.s.d[B]	*0.35*	*0.9*	*182*		*0.32*	*1.1*	*142*		*0.37*	*1.4*

[A] number in parenthesis indicates the treatment from Table 1.
[B] if P< 0.05 then l.s.d calculated at P=0.05, and if P was between 0.05 and 0.10 then l.s.d calculated at P=0.10.
[C] Canola yields in 1996 were reduced (expected yield = 2.0-2.5 t/ha) due to hail damage during flowering on the 18/9/96, which caused an estimated 30-50% yield loss; only minimal leaf damage was evident in wheat crops

Table 5. Simulated yield penalty and differences in available soil water for wheat cropping after lucerne, as compared to wheat production in a continuously cropped system.

Year	1	2	3	4	5
Yield penalty (kg/ha)	400	152	180	175	26
Difference in soil water at sowing (mm)	48	27	20	10	0
Difference in soil water at anthesis (mm)	40	25	18	7	0

Results and discussion

Water

The amount of soil water available for crop growth after pastures was considerably less (44-51 mm) than after annual crops (Table 2). Only small and non-significant differences in PASW were detected in the top 1.0 m in both years. Most of the difference (76-86%) in PASW occurred between 1.0 to 2.0 m. There was no evidence from grain yield data in 1996 that the first (canola) or second (wheat) crop grown after lucerne suffered reduced grain production due to decreased water availability (Table 4). The impact of less residual soil water after lucerne compared to continuous cropping on wheat production was simulated over 100 x 10 years of variable weather conditions. An average soil water difference of 48 mm (9 mm 0-1 m, and 39 mm 1-2 m, as calculated from Table 2) between lucerne and annual crops was used as an initial input for the first year of wheat production and all other inputs (eg. soil N, time of sowing) were the same for both scenarios. Simulat-ions of grain yield for the first wheat crop after lucerne predicted a small median yield reduction of 0.4 t/ha compared to the continuously cropped scenario (Table 5). This median yield loss was reduced to <0.2 t/ha in the 2nd, 3rd and 4th crops, and within 5 years there was no predicted yield penalty (Table 5). This result reflects the progressive decrease in differences in soil water between the two scenarios. As the differences in soil water between continuously cropped wheat and wheat after lucerne decreased, so did the median yield penalty. The results from this study indicate that the risk of a large yield loss for crops grown after lucerne in the Wimmera is low, and should not present a major constraint to the adoption of lucerne within the region. This is because lucerne did not create a large soil water deficit from 0-1 m, which is the predominate rooting zone of annual crops. Larger yield penalties are more likely to be a problem in the northern cropping-belt of Australia, where annual winter crops often rely on soil water stored after summer rainfall (7). Summer rainfall in the Wimmera is generally low (<100 mm) and ineffective, and crop yield is determined primarily by growing season (April to October) rainfall.

Nitrogen

The largest amount of SMN before sowing in 1995 was after a wheat crop (91 kg N/ha) grown in the drought year of 1994 (Table 3). This is likely to have resulted from a carry-over of N fertiliser (43 kg N/ha applied on 27 June 1994) which was not used by the previous low-yielding, droughted wheat crop (1.3 t/ha). There was no significant difference in SMN between the other treatments containing field pea and pasture (either prepared for cropping or within existing stands). In 1996, the concentration of SMN detected after the field pea crop (101 kg N/ha) was substantially greater than after the other crops and pastures (Table 3). The 1995 field pea crop did not appear to utilise the N fertiliser carried over from the previous 1994 wheat crop, and a high proportion of the profile SMN (47 out of 101 kg N/ha) was found at 50-100 cm.

Measurements of plant ^{15}N natural abundance undertaken at the experimental site confirmed that the majority (92%) of the field pea N requirement was met by N_2 fixation rather than the uptake of SMN (6). The quantity of SMN after pasture (lucerne removed) was greater than non-legume crops (canola and wheat) and remaining areas of pasture (Table 3). This pasture (Treatment 5) had a large annual medic component in 1995 (1.9 t/ha, 6). Compared to continuous cropping treatments, pasture provided a flow-on N benefit to the following canola crop in 1996, which was equivalent to pre-drilling 46 kg N/ha of N fertiliser (Table 5).

Despite some benefits in fertility, large responses to N fertiliser were still observed in crops following pastures; in grain yield (increases of 0.33-0.55 t/ha for canola, 1.0 t/ha for wheat), protein (0.7-2.3% for canola, 1.3% for wheat) and oil yield in canola (124-205 kg/ha). The amount and distribution of SMN in the profile significantly affected both the grain yield and protein content of wheat in 1996 (Table 4). The addition of N fertiliser to wheat after canola increased yield, but grain protein was significantly greater for wheat after field pea, because more mineral N was present at depth (47 kg/ha, as above). Although providing some contribut-ions of N, the pasture phase in this experiment failed to supply sufficient N to following crops to maximise grain yield and quality.

The legume content of these mixed pastures varied from 27-72% in the years prior to cropping. Possibly a greater N benefit may have been obtained if legume-dominant (80%) pastures could be maintained in the 3 to 4 years before returning to the cropping phase. Removing the lucerne earlier (spring prior to cropping) may have also enabled a greater amount of organic N to be mineralised before cropping, as found in southern NSW (increases in SMN from 50 to 200 kg N/ha from early lucerne removal, J.F. Angus and M.B. Peoples, unpublished data).

Conclusions

The inclusion of lucerne into cropping systems of the Wimmera is an effective means of increasing water use, and may potentially decrease the long-term threat of dryland salinity within the region. The risk of a large yield loss for crops grown after lucerne in this environment is low, and there is some evidence of small improvements in N supply to crops following pasture. Yet despite the apparent benefits, there is likely to be some reluctance by farmers in the Wimmera to adopt a lucerne pasture phase unless greater and more consistent improvements in soil fertility can be demonstrated. A legume-dominant (80%) pasture phase may provide both (i) a larger soil N input, and (ii) greater flow-on benefits to following non-legume crops, than the legume/grass mixtures investigated in this study.

Acknowledgments

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