Soil water under lucerne phase and companion cropping systems.

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Abstract

In southern Australia, lucerne (*Medicago sativa*) is the herbaceous perennial most likely to slow or halt the spread of salinity. To achieve this, it must: (1) reduce leakage and groundwater recharge; and (2) be widely adopted. In this paper, we examine the impact of lucerne on soil water storage for both phase (3-5 years of lucerne followed by an extended phase of cropping) and companion (simultaneous production of lucerne and crops) cropping systems. Production modelling, the role of lucerne management in minimising competition with a companion crop, and the influence of spatial arrangement on competition and crop yields are covered in related papers. Sites were established near Condobolin (NSW), Temora (NSW), Rutherglen (VIC), Esperance (WA), Katanning(WA) and Meckering (WA).Lucerne effectively depleted soil water below the root zone of annual crops and pastures at all sites under both systems, drying the soil by an extra 50-100 mm. The presence of a competing crop, lucerne suppression, supplementary irrigation and nitrogen addition, and lucerne winter activity rating, had at most minor effects on soil water extraction compared with water extracted by lucerne as a monoculture. Minimum lucerne density for soil water extraction varied between sites, but was always <12 plants/m^2 The soil water depletion measured in these trials is likely to have a substantial impact on groundwater recharge and the rate of groundwater rise. We concluded that lucerne incorporation under either farming system will achieve desirable hydrological outcomes, and this expands the potential for broad-scale lucerne adoption.

Key words

Dryland salinity, recharge reduction, perennials

Introduction

In southern Australia, dryland salinity continues to expand as the landscape slowly comes to equilibrium with the changed hydrology induced by broad-scale clearing of native vegetation. In Western Australia alone, the area currently affected by dryland salinity is estimated at nearly 1 Mha, and in the absence of preventative action or prolonged decrease in rainfall, is expected to expand to between 2 and 4 Mha (McFarlane et al. 2004).

The most promising preventative action is the incorporation of perennial plants into current farming systems. Perennials often have the capacity to grow roots deeper than conventional annual crops and pastures, or can respond to out-of-season rainfall, or both. Consequently, many perennials can extract more water from the soil than conventional crops and pastures, allowing the soil to soak up more water at times of water excess, thereby reducing leakage and groundwater recharge. Substantial effort has been put into identifying suitable perennials for inclusion into farming systems, but at this stage, the best option by a considerable margin is lucerne (*Medicago sativa*).

The hydrological efficacy of lucerne has been demonstrated at many sites around southern Australia (Ward et al. 2006). Furthermore, lucerne fits well into existing farming systems, in which a period of several years (a *phase*) of lucerne pasture is followed by a phase of cropping, before returning to a lucerne phase. This is known as a phase rotation. However, despite lucerne's hydrological efficacy and ready incorporation into farming systems, its adoption has been slow.

One of the major constraints to lucerne adoption is the cost of establishing the pasture, and further costs associated with lucerne removal prior to a cropping phase. However, there is another option. Since annual crops grow during winter and spring, and lucerne's main growth period is late spring to summer, it may be possible to accommodate both crop and pasture production in the same 12-month period. Such a system, known as *companion cropping*, would involve sowing crops into established but suppressed lucerne pasture in late autumn or early winter, and harvesting the crop early in summer, leaving the lucerne to grow after crop harvest. In this farming system, there is no cost for lucerne removal, and the length of the lucerne phase is extended, increasing both the period of hydrological protection afforded by lucerne, and the interval between costs associated with lucerne re-establishment.

Companion cropping is already being trialed and adopted in some regions of southern Australia, but the impact of cropping and lucerne suppression on soil water extraction is not known. Similarly, the impact of cropping on lucerne plant density, and the effect of reduced lucerne plant density on soil water extraction, is poorly understood. In this research, we collate results from many trials in NSW, VIC, SA and WA, and compare soil water extraction by lucerne in a phase farming system with soil water extraction by lucerne in a companion cropping system. The role of lucerne plant density in maintaining a dry soil buffer is also investigated.

Methods

Trials comparing phase rotations with companion cropping systems were established in NSW near Condobolin and Temora, in VIC near Rutherglen, and in WA near Katanning. At the Condobolin and Rutherglen trials, treatments were set up to examine the impact of supplementary irrigation and nitrogen fertilizer addition. Nitrogen fertilizer was also investigated at the Temora site. Treatments at the Katanning site included the impact of lucerne winter activity (Humphries et al. 2004). At all sites, lucerne was established in the first year of the trial, and cropping commenced from the second year onwards. Soil water contents were measured with a neutron moisture meter at all sites.

Trials examining the impact of lucerne plant density on soil water extraction were established in WA near Katanning and Esperance (for details see Lyons and Latta, 2004), and Meckering. In all trials, lucerne was sown at 2, 4, and 8 kg/ha, and at 1 kg/ha for trials at Esperance and Katanning, in a randomized block design. Soil water extraction was measured with a neutron moisture meter.

Crop and pasture production, and spatial arrangement of lucerne within crops, were also investigated within this project, and are the subject of other papers presented at this conference (Fedorenko et al. 2006; Harris et al. 2006).

Results and Discussion

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In all trials, lucerne was successful in establishing a large soil water deficit (SWD) in autumn compared with rotations that did not include lucerne. The magnitude of the SWD was in general agreement with previously reported values (Ward et al, 2006). Furthermore, there was little practical difference in the magnitude of the SWD created by lucerne grown as a monoculture, or grown in conjunction with grain crops (Table 1).

Soil water deficits for trials near Temora and Rutherglen were mostly generated by use of summer rainfall, rather than water uptake by lucerne from deeper in the soil. For these trials, the autumn soil water deficit was variable depending on the amount of summer rain received. Lucerne in trials near Condobolin and Katanning generated substantial soil water deficits in all years, due to water uptake from deep in the soil.

In general, soil water deficits created by lucerne were not strongly influenced by pre-crop or in-crop suppression of lucerne, nitrogen addition, or irrigation. Varieties with greater winter activity tended to produce slightly greater soil water deficits in the trial at Katanning (Humphries et al. 2004), but this effect was minor compared to the difference between the presence or absence of lucerne.

Lucerne density

Within the range of lucerne plant densities established in our trials (7-29 plants/m^2), there was little difference in soil water extraction. All lucerne densities created larger soil water deficits than annual pastures for the second and subsequent years (Table 2). Significant differences in SWD at the Katanning trial indicated that densities below about 12 plants/m^2 were less effective than higher plant densities. However, data from Meckering indicated the SWD kept on increasing with time despite densities falling to 3 plants/m^2. Virgona (2002) concluded that a density of around 5 plants/m^2 was a minimum for greater soil water extraction.

Table 1. Soil water deficits (? standard error) generated during the summer following various lucerne and crop treatments. Values for lucerne monoculture are in bold, companion cropping in italics, and crop monoculture in plain text. Codes represent treatments, with the "/" symbol used to separate growing seasons. L = lucerne; L* = lucerne terminated in the spring; B = barley; C = canola; T = Triticale; W = wheat; I = irrigated; S = lucerne suppression in crop; N = additional fertilizer nitrogen added; subscripts refer to lucerne winter activity rating.

Trial	Treatment code	SWD developed (mm)			
		Year 1	Year 2	Year 3	Year 4
Condobolin	L / L-I / L	**161?4**	**199?10**	**177?15**	
	L / L / L-I	**159?2**	**196?4**	**139?29**	
	L / B-I / W	**152?5**	148?13	87?22	
	L / B / W-I	**152?4**	164?4	52?14	
	L / B-L / W-L-I	**157?3**	*196?13*	*170?16*	
	L / B-L-I / W-L	**159?2**	*188?9*	*167?20*	
	L / B-L-N-S / W-L-N-S-I	**151?16**	*219?20*	*196?23*	

	L / B-L-N-S-I / W-L-N-S	**156?5**	*193?15*	*150?14*	
Temora	L / L / L / L*	**154?15**	**149?12**	**136?21**	**122?25**
	L / L / L-W / L-C	**165?7**	**146?11**	*142?14*	*155?12*
	W / C / W / C	92?6	89?8	69?10	153?18
Rutherglen	L / L / L	**95?4**	**104?6**	**120?7**	
	L-I / L-I / L-I	**100?3**	**111?3**	**119?3**	
	L-W / L-T / L-W	*85?1*	*89?5*	*103?2*	
	L-W-I / L-T-I / L-W-I	*82?5*	*106?2*	*113?1*	
	W / T / W	63?10	61?14	87?11	
	W-I / T-I / W-I	57?4	48?3	78?2	
Katanning	L_5 / L_5 / L_5 / L_5	**179?4**	**206?4**	**218?3**	**211?2**
	L_{10}-W / L_{10}-W / L_{10}-W / L_{10}-W	*163?5*	*199?9*	*204?10*	*202?9*
	L_5-W / L_5-W / L_5-W / L_5-W	*151?11*	*194?9*	*203?11*	*201?10*
	L_2-W / L_2-W / L_2-W / L_2-W	*141?16*	*186?16*	*195?15*	*194?15*
	$L_{0.5}$-W / $L_{0.5}$-W / $L_{0.5}$-W / $L_{0.5}$-W	*136?8*	*176?15*	*186?14*	*184?12*
	W / W / W / W	86?4	112?4	96?7	104?12

Table 2. Lucerne plant densities and autumn soil water deficits.

Trial	Sowing rate (kg/ha)	Year 1		Year 2		Year 3		Year 4	
		Density (/m2)	SWD (mm)	Density (/m2)	SWD (mm)	Density (/m2)	SWD (mm)	Density (/m2)	SWD (mm)
Esperance	1	13?1	53?3	12?1	43?3	9?1	61?4	7?1	49?4
	2	18?2	54?5	16?2	44?6	11?1	60?5	8?1	52?5
	4	24?1	44?4	24?1	41?5	12?1	56?6	10?2	44?6
	8	27?1	45?2	36?3	43?2	12?1	59?2	11?1	46?2
	Annual	0	50?2	0	32?2	0	39?2	0	32?1
Katanning	1	15?2	79?11	14?3	128?13	12?1	135?9	9?1	125?4
	2	19?1	83?17	23?1	156?21	16?3	169?19	14?2	176?21
	4	25?3	88?7	27?3	169?9	22?5	171?10	17?5	172?16
	8	29?9	107?15	28?6	164?17	24?6	174?18	17?6	189?26
	Annual	0	107?7	0	98?7	0	117?7	0	76?4
Meckering	2	22?2	61?5	22?3	113?11	15?1	150?17	3?1	167?14
	4	36?2	64?7	34?3	118?17	23?2	150?20	7?1	170?25
	8	48?5	77?10	41?3	124?10	24?2	152?17	11?3	177?10
	Annual	0	43?3	0	80?3	0	62?3	0	98?3

Under a companion cropping system, lucerne densities may decline more rapidly, especially where lucerne suppression is practiced (Latta and Lyons, 2006). Therefore, minimum lucerne densities for maintaining hydrological protection need to be established. Latta and Lyons (2006) demonstrated that for some soil types and climatic conditions in WA, lucerne densities of <5 plants/m^2 in a companion cropping system were sufficient to maintain dry soil profiles. Our results also suggest that there may be variation in minimum lucerne density associated with soil type and climate, and further research would better quantify this important question.

Conclusions

Lucerne effectively generates large soil water deficits, thereby providing hydrological protection against deep drainage. Lucerne's effectiveness was not affected by the presence of a crop in a companion cropping system. Furthermore, lucerne suppression, or the addition of supplementary nitrogen or water, did not substantially affect soil water extraction. Our research indicates that lucerne incorporated as part of a companion cropping system will be as hydrologically effective as lucerne incorporated as part of a phase rotation system. This increases the flexibility of lucerne in farming systems, and may lead to greater lucerne adoption in southern Australia.

Acknowledgements

Thanks to the CRC for Plant-Based Management of Dryland Salinity, and the Grains Research and Development Corporation, for supporting this research. We also wish to acknowledge other members of the research team not directly contributing to this paper, including Tom Bailey, Bill Bellotti, Clayton Butterly, Wen Chen, Michael Crawford, Jeff Hirth, Don Gaydon, Christopher Loo, Soheila Mokhtari, and Michael Robertson. Their thoughts and advice have been invaluable throughout the project.

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