Phase farming using lucerne in crop rotations

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Abstract

A field experiment using lucerne grown for two, three, or four years in rotation assessed the potential for phase farming to de-water soil. Crop yields after lucerne were generally similar to or higher than yields under continuous cropping, although were decreased for the first crop after lucerne in a very dry season. Lucerne increased the water storage capacity of soil to at least 250 mm compared with approximately 100 mm under annual crops. Soils could be cropped for 1-2 years following lucerne before soil water content returned to control levels; under certain conditions this period could be extended to 3-5 years. This work demonstrated that phase farming can reduce the hydrologic imbalance occurring under annual crops.

Key words: *Lucerne, crop, phase farming, soil water, drainage, rotation.*

Dryland salinity and/or soil acidification are major land degradation problems threatening much of Australia's prime grain growing areas. Both problems arise from the mis-match in timing between supply of water and nitrogen to, and demand by, crops. In southern Australia, winter rainfall substantially exceeds evaporation over the May-August period of soil water repletion (7), resulting in much more drainage than under the original native vegetation. Amounts of drainage in much of the cropping zone are estimated typically to be 20-90 mm/yr (5, 8), but losses are highly episodic due to rainfall variability (3).

Phase farming (alternating a series of crops with a few years of perennial species) is one of the most promising innovations for controlling recharge in cropping areas. The system exploits the storage capacity of the deep subsoil, allowing it to fill during the cropping years, and emptying it under the perennial. Lucerne has most potential of commercial species to fit in with ley farming enterprises (4).

Methods

A field experiment was conducted at Rutherglen on a duplex soil (B horizon below 20 cm) to determine the effect of two, three or four years of lucerne on grain production and de-watering of soil. There were 6 replicates of 8 treatments (plot size 20 m x 15 m); CC (continuous crop), AP (annual pasture) and CL (continuous lucerne, cv. Pioneer 69), and rotation treatments of 2L95 (2 years lucerne, cropped from 1995), 3L96 (3 years lucerne, cropped from 1996), 4L97 (4 years lucerne, cropped from 1997), 2L96 (2 years lucerne, cropped from 1996) and 3L97 (3 years lucerne, cropped from 1997). Lucerne was sown in either spring 1993 (established plant density 46 plants/m^2) or autumn 1994 (28 plants/m^2). Lucerne was harvested by cutting during the growing season and grazed periodically over summer. Crops were Katunga wheat in 1993, Gungurru lupins 1994, Katunga wheat 1995, Oscar canola 1996 and Swift wheat in 1997. The CC treatment had 50 kg N/ha applied in 1997 pre-tillering. To change phases lucerne was chemically removed 4-5 weeks before sowing in May.

Grain yield was determined. Soil water content was measured with a calibrated neutron moisture meter (4 replicates). Sampling depth was to 1.8 m (20 cm increments), except for CC and CL where it was 2.7 m until 1996, and 5.5 m in 1997. A simple water balance model (7) was used to assess the likelihood of drainage.

Results

Climatic data

Rainfall and the excess of rainfall over potential plant water use over the soil water repletion period of May-August (7) is shown (Table 1). Both 1995 and 1996 were wet, showing a large excess of rainfall from May to August.

Agronomy

Table 1: Rainfall and estimated plant water use (mm) data at Rutherglen, Victoria for 1995-97.

	1995	1996	1997	Long term av.
Annual rainfall	729	664	395	597
Apr-Oct rain[a]	490	467	274	397
May-Aug rain	350	284	190	239
May-Aug Et[b]	107	98	104	106
Winter excess of rain over Et	243	186	86	133

[a]April-October rainfall defined as growing season rainfall

[b]Evapotranspiration (Et) was estimated to be 0.6 times pan evaporation.

Table 2: Crop yields (t/ha) 1995-97.

Treat.	1995 wheat	1996 canola	1997 wheat
CC	5.40	1.66	4.74
2L95	4.85	2.09	4.81
3L96	-	2.24	4.95
2L96	-	2.10	4.80
3L97	-	-	3.87
4L97	-	-	3.55
$lsd_{5\%}$	ns	0.34	0.28

There was no significant effect of lucerne on wheat yield in 1995 (Table 2). If growing season rainfall is assumed to be April-October (Table 1), French-Schultz potential yields (2) for wheat of 20 kg grain/(mm growing season rainfall minus 110 mm) were not reached (13-14 kg grain/mm). In 1996 canola following lucerne gave yield increases of 26% (2L95, 2L96) to 35% (3L96) compared with CC (P<0.05) (Table 2). Potential yields for canola were low (5-6 kg grain/mm), probably due to two substantial periods of waterlogging.

In 1997, the first crops following lucerne (3L97, 4L97) had lower yields than other treatments (P<0.05) but yields of second and third crops were similar to CC (Table 2). Soil to 1.8 m depth was as dry under first crops as under CL, and drier (P<0.05) than for all other crop treatments for most of the growing season. In May soil under first crop treatments was 60-90 mm drier than under second crops, and 120 mm drier than under CC. ?All crops showed signs of water stress at anthesis, with first crop treatments showing the most severe symptoms (flag leaf wilted, other leaves rolled); first crops were in the order of 50-70 mm drier than second crops and 80-90 mm than third and CC treatments at anthesis. There was only one substantial rainfall event (25 mm) between anthesis and harvest. Despite the dry year yields of all crops were high in 1997 (Table 2) and French-Schultz yields for wheat were exceeded for all treatments; 22-24 kg grain/mm were achieved for first year crops following lucerne and 29-30 kg grain/mm for second, third and continuous crop treatments.

Soil water

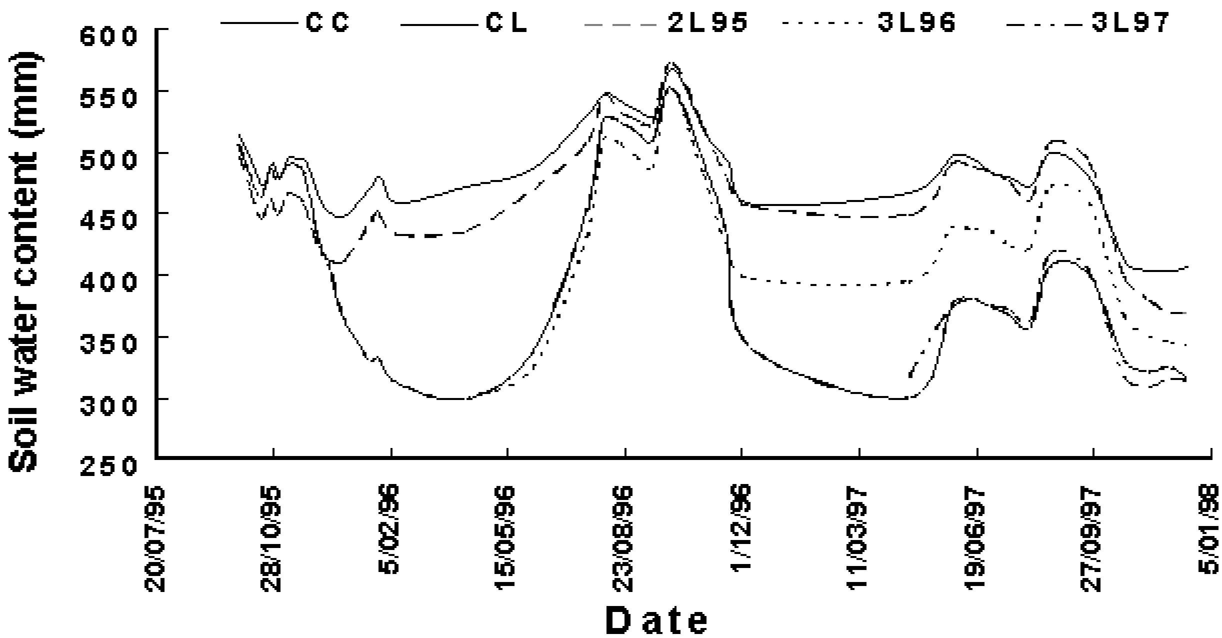

Figure 1

Soil water content of selected treatments (CC, CL, 2L95, 3L96, 3L97) are presented (Fig 1). Soil under lucerne became approximately 150 mm drier than CC. ?Maximum period of soil water extraction under lucerne was from October-December, with further slow extraction through summer. To 1.8 m depth the maximum soil water deficit reached under lucerne (from spring,1996 to autumn, 1997) was 250 mm compared with 100 mm under CC. When the extra soil water extraction below 1.8 m depth (to 3 m) under lucerne was taken into account, a further 65 mm of extra soil water storage capacity was created (data not shown). The CC treatment reached its driest point in early 1998, indicating an upper limit of 160 mm soil water deficit was possible.

Soil water content under 2L95 was similar to CC (P0.05) by sowing in 1996 and thereafter (Fig 1). Thus, the de-watering effect of two years lucerne was lost following one crop in a wet year. Where lucerne had been grown for two or three years (2L96-data not shown, 3L96), and first cropped in 1996 (moderately wet year first crop, dry year second crop), the soil remained drier than CC to 1.8 m depth following 2 crops to date. Where the first crop following lucerne was grown in a dry year (3L97, 4L97-data not shown), the soil water content under these treatments was similar to CL (Fig 1).

Applying Whitfield's model (7) to data collected (100 mm soil water storage capacity generated under crops and 250 mm under lucerne, and adding the estimated average plant water use of 106 mm over the soil water repletion period, (Table 1), threshold May-August rainfall limits of 206 and 356 mm can be used to assess the likelihood of drainage occurring in a given year for crops and lucerne respectively. Over 85 years' rainfall records (1913-97), May-August rainfall exceeded 206 mm in 60% of years, and exceeded 356 mm in only 7% of years. ?Predictions using Whitfield's model were that that water losses would have occurred under CC in both 1995 and 1996, and losses would not have occurred in either year under CL.

Discussion

Despite soil being drier for sowing crops following lucerne, yield of the first year canola (3L96) in 1996 was similar to or higher than second year crop and CC treat- ments. Rainfall in June-August resulted in favourable soil water conditions for crop establishment and growth. ?However, in the dry year of 1997 first year wheat yields were lower where lucerne had previously been grown. ?Growing season conditions may be a more major determinant of crop yield than soil water content at sowing in this environment. Soil mineral nitrogen levels are also important for crop yield and quality (data not presented).

The large soil water storage capacity established after 3 years of lucerne (250 mm to 1.8 m depth, and over 300 mm to 3 m depth) indicates considerable potential for this perennial to reduce water losses. In average years (winter excess rainfall over plant water use of 133 mm at Rutherglen), full soil water repletion to 1.8 m depth under lucerne would occur after two crops in this environment. Up to 4-5 crops following lucerne may be possible where water extraction of the perennial occurs to 3 m, in a run of dry seasons occurs, and/or where excess winter rainfall is lower than that at Rutherglen.

The water balance model of Whitfield (7) applied to these study data suggests that water losses under lucerne should be substantially reduced compared with losses occurring under annual crops. Water losses in duplex soils can occur through surface runoff, subsurface flow and deep drainage (6). The partitioning of these losses was not identified in this study.

Soil water repletion occurred more rapidly under lucerne than annual species. The reasons for this are unclear but could be due to the initially more rapid infiltration of water into drier soil and less runoff and/or subsurface flow occurring under lucerne. Reduced runoff and subsurface flows have been measured under perennial grasses compared with annual pastures (5). ?The implications for lower runoff under perennial species could be important in catchments which are major suppliers of fresh water to down-stream users. It is possible that soil structure may have changed under lucerne, although demonstrating such changes could be difficult (H. Cresswell pers. comm.). Further understanding of re-wetting processes under lucerne and the partitioning of water losses in duplex soils is needed.

Conclusion

Lucerne can reduce the hydrologic imbalance of current cropping practices. Further understanding of the partitioning between water losses (surface runoff, subsurface flow in duplex soils and deep drainage) under crops and lucerne is needed. Drier soil conditions for crops following lucerne may not be detrimental to yield in this environment, provided favourable seasonal conditions follow sowing. Large scale adoption of systems such as phase farming is important if salinisation is to be reduced (2). Developing grazing management guidelines to optimise de-watering with practical and profitable production which can be adopted by the majority of farmers remains a challenge.

Acknowledgments

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