What is limiting productivity and water use of cereals in the southern Wimmera of Victoria?

R.D. Armstrong, R Flood and C Eagle

Agriculture Victoria – Horsham, Victorian Institute for Dryland Agriculture, Horsham, Victoria.

ABSTRACT

A field trial was undertaken in 1999 to gain a better understanding of factors responsible for poor grain yields of cereals in the southern Wimmera region of Victoria. There was a strong yield response of wheat (cv. Goldmark) to treatments that were designed to improve soil structure and/or to reduce effects of overcome waterlogging (gypsum, deep ripping plus gypsum, or application of high rates of pig bedding straw, raised beds). Enhanced nutrition (N, Cu and Zn fertiliser) or spring sowing had no beneficial effect on yield although N application significantly increased grain protein. Measurements taken at grain maturity indicated no cropping treatment appeared to significantly enhance the use of soil water at depths > 60 cm. In contrast a perennial pasture effectively used soil water to 140 cm. Poor soil structure rather than 'high rainfall' *per se* appears to be the principal factor limiting crop yields in this region.

KEY WORDS

Waterlogging, sodicity, soil structure, raised beds, nutrition.

INTRODUCTION

Poor water use efficiency (WUE) has been identified as a major constraint to cereal productivity in Victoria (2) as well as contributing to rising water tables and increased salinisation. Inadequate nitrogen (N) nutrition has often been blamed as the principal cause of low WUE (5) but there is growing evidence (4) that subsoil limitations such as high boron, sodicity (structural constraint) and salinity are responsible, at least in the Wimmera and Mallee regions.

The southern Wimmera differs significantly from other cropping regions of north western Victoria. Although rainfall (> 500 mm), and therefore yield potential, is comparatively high, the soils are poorly structured and waterlogging often occurs during winter (1). At present there is relatively little cropping in this region due to farmer's experiences of repeated crop failures. This paper reports results from a trial that was designed to provide a better understanding of the principal factor/s limiting grain yields in this area. This knowledge can then be used to develop management strategies that will allow farmers to increase yields and reliability of crops in this area whilst minimising salinisation.

MATERIALS AND METHODS

A field trial was established in 1999 at Brimpaen in the southern Wimmera (ca. 40 kms south of Horsham) which receives approx. 500 mm annual rainfall. The trial was located on a highly sodic grey clay with an exchangeable sodium percentage increasing from 15 in the surface 10 cm to > 25 lower in the subsoil. The site had been sown to canola in 1998. A trial was established to assess the relative importance of nutrition, soil structure, and waterlogging, both singularly and in combination, on grain yields and water use of wheat. A pasture (comprising both annual and perennial species) was also included due to the reported benefits (6) of perennial species on maximising water use that could be compared to cropping treatments. The trial was a randomised complete block design, with 4 replicates. The 11 treatments were: (i) Control (- N) (ii) plus N (iii) High fertility (extra N + Zn and Cu) (iv) Pig bedding litter (20 t/ha) (v) Gypsum (topdressed @ 8 t/ha) (vi) Deep ripping + gypsum (vii) Raised beds (viii) Raised beds + High fertility (ix) Works (raised beds, gypsum, high fertility and pig bedding litter) (x) Pasture (phalaris, lucerne and subclover) and (xi) Spring sown (on conventional beds plus N).

Plots were 25 m x 11m. A basal application 15 kg P/ha (as double superphosphate) was applied at sowing to all treatments. A basal application of 25 kg N/ha (as urea) was lightly incorporated at sowing followed by a subsequent top dressed application of 25 kg N/ha across all treatments except the control and pasture treatment. For high fertility treatments a further application of 25 kg N/ha was top dressed at mid tillering and a foliar application of zinc (Zincsol @ 2 l/ha) and copper (Coppersol @ 1.5 l/ha) was applied. Deep ripping comprised a single bar rip along the length of each plot every 1.8 m (total of 5 /plot) to 25 cm followed by a subsequent pass to 50 cm. Gypsum was applied via a boot with each ripping pass to give a total of 8 t/ha of gypsum in the ripping slot. This was supplemented by a further 3 t/ha of gypsum top dressed across the whole plot to give a total application of 11 t gypsum /ha. Wheat (cv. Goldmark) was sown on 4 June. For the spring sown treatment, wheat cv. Silverstar, a shorter season variety, was sown on 18 August. In raised bed plots, which comprised 6 rows vs the 8 rows in conventional bed plots, application rates of seed and fertiliser were adjusted to give the same total quantity across all treatments. Data are presented for grain yield (header cut), grain nitrogen content (analysed by Leco system), gravimetric soil water content and soil resistance (cone penetrometer, Agridry Rimik Pty Ltd). Measurements indicated no significant difference ($P < 0.05$) in soil water content between treatments at the time of cone penetrometer measurements.

RESULTS

Rainfall in 1999 was well below average with total rainfall of 376 mm (average > 500 mm), of which 294 fell during the growing season.

Improving crop nutrition (N, Zn and Cu) did not affect grain yields (Figure 1). However, all other treatments, with the exception of spring sown wheat, produced significant yield increases (up to 2 t/ha or 63%) compared to the control. The higher grain yields in the treatments with improved soil structure and raised beds corresponded to increased harvest index (Table 1).

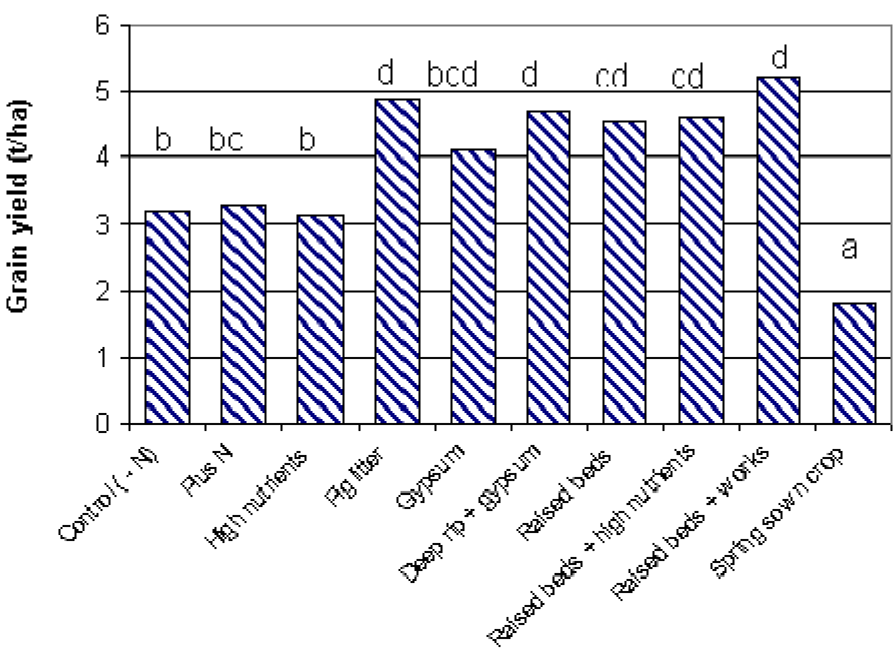

Figure 1. Effect of different management treatments on grain yield of wheat at Brimpaen (1999). Treatment means with same letter are not significantly different (P = 0.05).

Although adding N fertiliser had no effect on grain yields, it significantly increased both kernel weights and grain protein compared to the control. The total N in the grain in the raised beds + works treatment was nearly twice that of the control.

Despite the improvements of grain yield, crop management was only partially successful in improving the use of soil water (Figure 2). In the upper part of the soil profile (0 – 50 cm), soil water was lowered significantly ($P < 0.05$) in treatments designed to improve soil structure such as adding pig bedding litter, deep ripping or using raised beds. However, these treatments had little effect in middle parts of the soil profile (50 – 100 cm). Only the pasture treatment appeared to effectively reduce soil water content throughout the entire soil profile.

Soil resistance, as measured in August 2000 under high soil moisture conditions, was low in upper parts of the soil profile but increased steadily with depth (Figure 3). Compared to the control treatment, adding gypsum alone or in combination with deep ripping significantly decreased penetrometer resistance,

especially at depths below 200 mm. Surprisingly, adding large quantities of organic matter, in the form of pig bedding litter, only slightly reduced resistance.

Table 1. Effect of management regime on yield components and protein at Brimpaen (1999).

Treatment	Harvest Index	Kernel Weight (mg)	Grain protein (%)	Grain nitrogen (kg N/ha)
Control (- N)	0.31	41.7	9.4	51.7
Plus N	0.30	44.6	12.1	70.3
High nutrients	0.29	45.3	12.7	70.3
Pig litter	0.34	45.0	11.6	98.7
Gypsum	0.30	43.4	10.8	78.0
Deep ripping + gypsum	0.33	43.7	11.3	92.7
Raised beds	0.33	41.3	10.3	82.2
Raised beds + high nutrients	0.33	42.4	11.8	95.4
Raised beds + works	0.33	42.1	11.1	101.5
Spring Sown (cv. Silverstar)	0.30	29.7	12.6	39.9
***l.s.d.* (5%)**	**0.03**	**1.9**	**1.0**	**21.5**

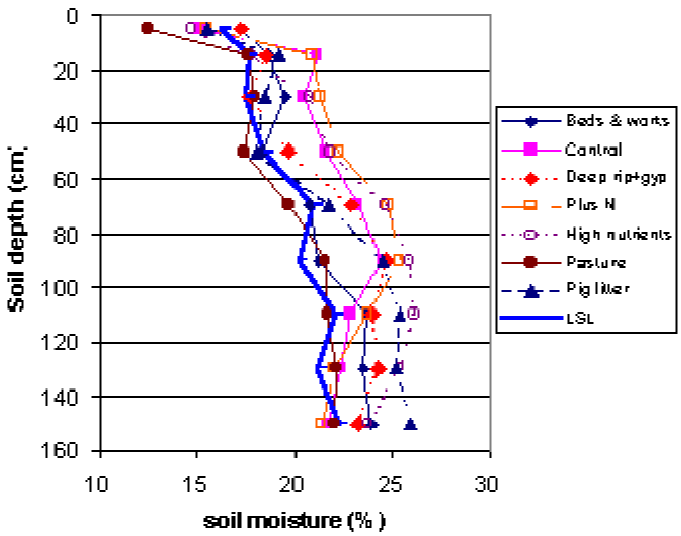

Figure 2. Gravimetric soil water at grain maturity at Brimpaen (1999). ***l.s.d.*** **(P = 0.05): treatment = 4.94 depth = 1.49 ; treatment x depth n.s. LSL represents the lower storage limit (-15 Bar).**

DISCUSSION

Grain yields were significantly improved by treatments that either directly (raised beds) or indirectly (eg. deep ripping, pig bedding litter) overcame the effects of waterlogging. In contrast, improved nutrition had little effect on yields, and assessments of root disease (data not presented) suggested that disease had little impact on yields. Shallow piezometers (at 35 cm depth) installed at the site indicated that the ground water table in control treatments was just below the soil surface for critical periods during the growing season. In contrast, in treatments where soil structure was improved the water table was much lower (> 35 cm) in the profile. Other studies in south west Victoria, but located in much higher rainfall zones eg. 700 mm annual rainfall (3) have highlighted the importance of waterlogging to yields in this region, especially when it occurs near anthesis. However the significance of the current trial is that 1999 was a drought year.

Despite no yield response, grain protein increased significantly when N fertiliser was applied. This protein response corresponded to larger kernel weights in lower yielding treatments. However, in the highest yielding treatments eg. raised beds + works, both protein and kernel weight was depressed, indicating that either the extra nitrogen applied was inadequate to meet crop demand or that the crop experienced drought stress during the grain filling phase. The latter explanation appears more likely as kernel size was depressed in the spring sown treatment despite protein remaining comparatively high.

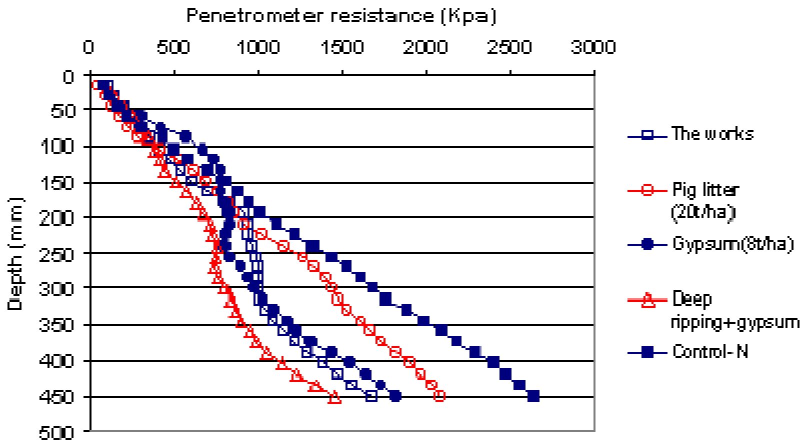

Figure 3. Effect of various management treatments on soil strength (cone penetrometer resistance) at Brimpaen (August, 2000). ***l.s.d.*** **(P = 0.05): treatment x depth = 343.**

Ironically, if grain yield was hampered by moisture deficit during grain fill, this was not reflected by the amount of soil water remaining in the profile at maturity. In all cropping treatments there was minimal use of subsoil soil water, despite very low rainfall during spring. Although there was comparatively little available water remaining in the upper soil layers in the higher yielding treatments eg. raised beds + works, pig bedding litter and deep ripping, these treatments still had little impact on soil water use deeper in the profile. Evidently these treatments were able to improve the physical environment in the upper part of the profile eg. reduced soil strength (Figure 3) or reducing waterlogging, to permit root growth and activity. However this affect did not extend to lower sections of the profile. This contrasts to other studies (7) on acid soils where deep ripping increased water use of wheat below the ripped zone in a dry season. This suggest that ripping may be effective where a plough pan is present but will be ineffective where obstacles to root growth extend throughout the entire profile such as occurs in highly sodic subsoils.

In contrast to the cropping treatments, the pasture had used most of the soil water down to 160 cm. Perennial pasture species such as lucerne and phalaris are well known for there ability to 'dewater' soils in high rainfall environments (6). This ability seems to extend to environments where subsoil conditions such as sodicity can inhibit the growth of annual species such as wheat. The inability of wheat to dewater the profile, even when the soil environment was significantly modified, has major implications for ground water recharge. Soils in the southern Wimmera are natural saline and potential increases in recharge rates will lead to the development of dryland salinity. However further studies where the full water balance eg. including runoff and percolation is determined, are required to verify this

ACKNOWLEDGMENTS

This work was funded by the Department of Natural Resources and Environment (Victoria) and the Grains Research and Development Corporation.

REFERENCES

1. Gardner, W.K. and McDonald, G.K. 1988. *Aust. J. Exp. Agric*. **28**, 607-15.

2. Hamblin, A. and Kyneur, G. 1993. Trends in wheat yields and soil fertility in Australia. DPIE/Bureau of Resource Sciences (Aust. Govt. Publ. Services, Canberra).

3. McDonald, G.K. and Gardner, W.K. 1987. *Aust. J. Exp. Agric*. **27**, 661-70.

4. Nuttall, J.N. , Armstrong, R.D. and Connor, D.J. 2001 *Proceedings 10th Australian Agronomy Conference*, Hobart. In press.

5. Ridge, P., Bell, A., Medway, J. and Clark, N. 1996. Families, Farming and the future: Probing water use efficiency and crop productivity in southern New South Wales, and in the Wimmera and Mallee of Victoria. FAST project – FM500 (Neil Clark and Associates, *Bendigo*).

6. Ridley, A.M., Christy, B., Haines, P.J., Dunin, F.X., Wilson, K.F. and the late Ellington, A. 2001 *Australian Journal of Agricultural Research.* **58,** *In press.*

7. Steed, G.R., Reeves, T.G., and Willatt, S.T. 1987. *Aust. J. Exp. Agric.* **27**, 701-5.