Seasonal expression of subsoil constraints in a Mediterranean-type environment

Mike Wong[1] and Senthold Asseng[2]

[1]CSIRO Land and Water, Underwood Avenue, Floreat WA 6014. www.csiro.au. Email mike.wong@csiro.au.
[2]CSIRO Plant Industry, Underwood Avenue, Floreat WA 6014. www.csiro.au. Email senthold.asseng@csiro.au.

Abstract

Wheat response to subsoil amelioration fluctuates seasonally in the Mediterranean-type environment of Western Australia (WA). We used APSIM to simulate this fluctuation and understand seasonal, soil and management factors so that the financial benefits and risks of subsoil amelioration are better managed. Simulations for a low (Buntine) and medium (Mingenew) rainfall location in WA showed little yield response to subsoil amelioration in dry years when root depth was limited by the depth of the wetting front and there was little subsoil water for crop use. Positive yield responses were greater in the wetter location as roots needed to reach deeper wetting fronts. The potential financial gains in average to good rainfall years can offset losses in dry and dry finish years.

Introduction

Subsoil constraints limit root access to water and nutrients. The expression of yield limitations due to water and nutrient deficiency is season and soil dependent (Wong and Asseng, 2006). This leads to difficulty in interpreting the results of field experiments since treating subsoil constraints can have positive, negative or no effect on grain yields (Jarvis 1986). A negative crop response may be due to poor crop establishment in freshly cultivated soils or displacement of hostile acidic or dispersive subsoil to the surface. In sandy soils of WA, this negative response is believed to be more likely due to the dynamics of water and nutrient availability compared to crop demand in a water-limited Mediterranean-type environment.

This uncertain crop response undermines financially sound recommendations to alleviate subsoil constraints. A model such as APSIM provides a means to extrapolate the results of field experiments spatially and temporally to understand the behaviour of the cropping system and the effect of soil properties, weather and fertiliser on yield. The aims of this work were to (1) to simulate the impact of increased mechanical impedance on wheat yields under different weather conditions for a low and medium rainfall location in WA and (2) to evaluate the seasonal risk and financial benefits of ameliorating traffic-induced subsoil compaction in a yellow sand.

Methods

APSIM uses layer-specific root hospitality (Rh) factors to simulate root growth responses to mechanical impedance down the soil profile (Asseng et al., 1998). The root mean square deviation (RMSD) of simulated root depths was 13 cm across four sites in WA. RMSD of simulated wheat yields was 0.4 t/ha for yields ranging from 1.0 to 4.0 t/ha (Asseng et al., 1998). Wheat yields were simulated for control (no compaction), mild, medium and severe traffic-induced compaction at 20-40 cm in sand using daily weather records for Buntine (average seasonal May to October rainfall 238 mm) and Mingenew (average seasonal rainfall 315 mm) each year for 1955 to 2004. Simulations were for initially dry or wet soil profile. Only the results for the initially dry soil profile are shown here.

Economic analysis

Simulated wheat yields with or without a severe (Rh = 0.01) compaction layer at 20-40 cm were sorted according to season tercile types. Gross margins were calculated using current price of wheat and average input costs of Aus $ 127 /ha plus $ 1 /kg N applied. Deep cultivation to 40 cm and soil stabilisation with gypsum costs $ 150 /ha every three years (M. Hamza, personal communication). As a best case-scenario, we assumed that the beneficial effect of deep cultivation remained constant throughout the 3-year period.

Results

Deep cultivating severe traffic-induced subsoil compaction increased simulated yields to control values at seasonal rainfalls > 150mm (Figure 1). Deep cultivating medium (Rh = 0.1) and mild (Rh = 0.2) subsoil compaction only increased simulated yields to control values at seasonal rainfalls > 250 mm. At lower rainfalls, yields from the deep cultivated control were lower than from mild and medium compacted soils.

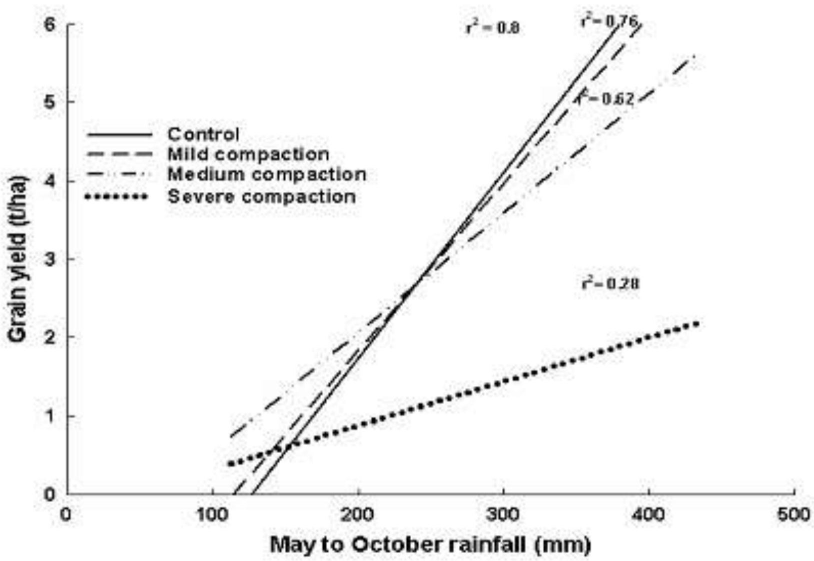

Figure 1. Regression of simulated wheat yields on seasonal rainfalls for a yellow sand.

In dry years, deep-cultivating a severe traffic-induced subsoil compaction resulted on average in financial loss (Table 1). Assuming that it is equally likely to have a dry, average and wet year over a three year period between re-cultivation, the loss in a dry year would be offset by gains in average to wet years. The average benefits over the three season types were greater at the wetter Mingenew location than in Buntine.

Table 1. Potential financial benefits of deep cultivating a strongly compacted layer at 20-40 cm in sandy soils at Buntine and Mingenew for three local season types.

Location ???	Season ?tercile ?type	Rainfall percentile (ascending) (%)	May - Oct rainfall range (mm)	Gross Margin ($/ha.year)		
				With severe compaction?	Compaction removed	Benefits from Deep-cultivation[a]
Buntine	Dry	100.0 - 66.6	113 - 203	-72	-1250	-53
?	Average	066.6 - 33.3	212 - 269	100	185	85

?	Wet	033.3 - 00.0	273 - 432	140	572	0432
		Average benefits over the three season types?				**155**
Mingenew	Dry	100.0 - 66.6	172 - 260	006	-14	-20
?	Average	066.6 - 33.3	266 - 345	247	454	207
?	Wet	033.3 - 00.0	349 - 520	279	844	565
		Average benefits over the three season types?				**250**

[a]Yield responses are APSIM predictions assuming initial deep-cultivation effect remained constant during the seasons, no adverse impacts on crop establishment and deep-cultivation increased potential rooting depth.

Conclusion

APSIM allows simulation of yield responses for specific soil, weather and management conditions to inform decisions on the potential value of subsoil amelioration. This together with on-farm experiments in growers' paddocks would improve strategic decision on investing in subsoil amelioration.

Acknowledgements

We thank GRDC for co-funding this work as part of its subsoil initiative SIP09 and Mr N. Khimashia and Ms K. Wittwer for technical support.

References

Asseng S, Keating B A, Fillery I R P, Gregory P J, Bowden J W, Turner N C, Palta J A, Abrecht D G 1998 Performance of the APSIM-wheat model in Western Australia. Field Crops Res. **57**, 163-179.

Jarvis R J 1986. Crop response to deep tillage. In M W Perry (ed.) A review of deep tillage research in Western Australia. West Australian Department of Agriculture Tech Report 3, pp 40-51.

Wong M T F and Asseng S 2006. Determining the causes of spatial and temporal variability of wheat yields at sub-field scale using a new method of upscaling a crop model. Plant and Soil **283**, 209-221.