Ripping yarns: 25 years of variable responses to ripping clay soils in south-eastern Australia

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Abstract

Soil compaction has re-emerged as a potential limitation to further yield improvements on clay loam soils in southern NSW but the few published studies are restricted to sodic clay soils. A survey of 39 paddocks across the region in 2004/5 revealed that few had sub-surface soil strengths <2.0 MPa, a commonly accepted threshold at which root growth is restricted, while around 40% had levels >3.0 MPa. A review of crop responses to deep ripping to 40 cm in the area from 1980 to 2005 showed yield responses in only 5 of the 15 crops measured (from 11 to 48% increase), despite consistent reductions in soil strength to <1.0 MPa, and 20 to 30% increases in early vegetative biomass at some sites. Experiments conducted at 9 sites across the region in 2007, a drought year, showed that ripping consistently reduced sub-surface soil strength from 2.5 - 4.0 MPa to 0.5 - 1.3 MPa, but early vegetative biomass increased at only 2 of the sites. Ripping had no effect on yield at 5 sites and significantly reduced crop yield/biomass at the remaining 4 sites apparently due to water loss associated with soil disturbance. In the face of these variable responses, we discuss the role of structural cracks and biopores which enable roots to penetrate high-strength soil and the prospects of identifying paddocks where long-term economic yield responses to deep ripping can be achieved.

Key Words

compaction, controlled traffic, deep tillage, root depth, deep ripping

Introduction

Soil compaction can reduce crop growth and yield in a range of cropping systems (Hamza and Anderson 2005). In southern Australia, yield responses to ripping compact subsoils are consistent (20-40% increase) on deep acid sands of Western Australia (Jarvis 2000), but variable on widespread duplex soils with sodic clay B horizons (Ellington 1986; Crabtree 1989). Variability in yield response to ripping is caused by the interactions between soil type and rainfall patterns, and the way in which these ultimately affect root growth, water-use and yield development at particular sites (Kirkegaard et al. 1993; Sadras et al 2005). There are few published studies on the occurrence and potential impact of soil compaction on the clay loam soils (Chromosols and Kandosols) of southern NSW despite the relatively high levels of soil strength (>2.0 MPa) measured in the region (Geeves et al. 1995), and widespread observations of taproot distortion in dicotyledonous crops (Lisson et al. 2007). This may reflect a lack of significant response to amelioration, or an assumption that compaction is not an issue on these soils. The 500-600 mm of equi-seasonal annual rainfall reduces crop dependence on stored soil water, and although dense, the soils can have significant structural and biological macro-porosity to assist water and root penetration (Geeves et al 1995). Renewed interest in compaction has been refocussed recently by a series of dry years since 2002 when capture and efficient use of water has been paramount, by the increasing adoption of controlled traffic farming in other areas (Chan et al 2006), and by declining canola yields thought to be in part due to subsoil constraints (Lisson et al 2007). We combined a paddock survey, a review of available data, and recent experimental results to consider the occurrence and impact of compaction on crop growth in southern NSW.

Methods

Paddock survey and compilation of data from ripping experiments

Penetrometer resistance was measured in 39 paddocks across the region (15 in 2004 on June 4; 24 in 2005 on August 17) as part of a larger survey investigating canola productivity (Lisson et al 2007). In each paddock resistance was measured at 5 random sites using a Rimik CP4011 cone penetrometer (standard 1.3 cm^2 tip) to a depth of 50 cm in 1.5 cm increments. The mean penetrometer resistance at 17.5 cm depth, which was below the disturbed layer, but wet to field capacity in both seasons, was calculated for paddock comparisons.

Previously published reports and unpublished data on crop responses to deep ripping in southern NSW/northern Victoria were compiled and summarised (Table 1). Some experiments included interacting treatments such as gypsum or lime application, which are discussed where relevant.

Ripping experiments in 2007

A series of field experiments were conducted at 9 sites across southern NSW in 2007, from Corowa in the south to Greenethorpe in the north, representing a range of common soil types and environments. At each site, replicated plots (2 to 4) were ripped in February/March under dry conditions using an Agroplow? deep ripper with tines spaced 45 cm apart and modified to deep inject dry gypsum at 3.5 t/ha at sites with sodic subsoils. Ripping depth was adjusted at each site to ensure penetration and shattering of the compact subsurface layer, but varied at each site according to the power capability of the available machinery (Table 1). Secondary tillage to prepare a suitable seedbed was carried out as required, and the plots were sown by collaborating farmers using commercial controlled traffic equipment in April/May 2007. Agronomic management of the crops ensured no limitation to plant establishment, nutrients, or weed, pest or disease control. Penetrometer resistance was measured in mid-winter (July-August) at each site when the top 40-50 cm of soils was wet to field capacity. Measurements were taken at 6 un-wheeled locations in each plot using the penetrometer described above. In the un-ripped control plots, the mean maximum penetrometer resistance in the 15 to 20 cm layer below the disturbed surface layer was recorded. In the ripped plots, the mean penetrometer resistance at the same depth was recorded for each plot based on measurements on and between the rip lines (0, 11 and 22 cm from rip lines). Crop establishment, vegetative biomass and grain yield were measured at all sites using samples taken from bordered quadrats (1 to 2 m^2) and plot headers.

Results

The survey revealed that few paddocks (2/39) had sub-surface layers (10-20 cm) with penetrometer resistance <2.0 MPa, while around 40% (16/39) had >3.0 MPa (Figure 1). The range in resistance was similar for both years, and there was no regional pattern in the data.

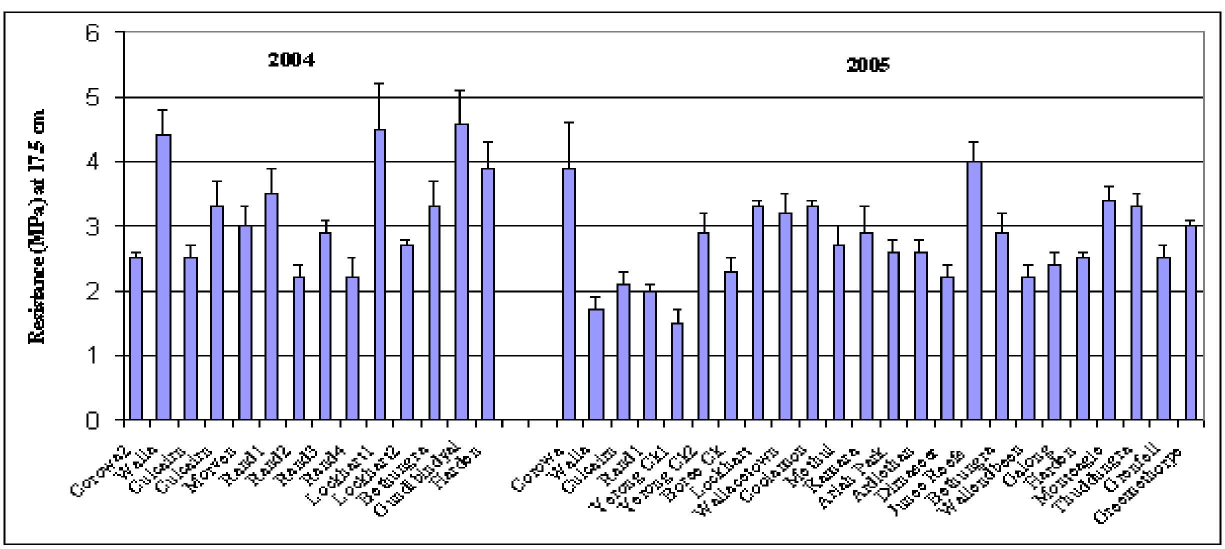

Figure 1. Penetrometer resistance (MPa) measured below the disturbed surface layer (17.5 cm depth) in winter for paddocks across southern NSW in 2004 and 2005.

The review of crop responses to deep ripping (to 40 cm) in the area from 1980 to 2005 showed yield responses in only 5 of the 15 crops measured (11 to 48% increases), despite consistent reductions in soil strength to <1.0 MPa, and 20 to 30% increases in early vegetative biomass at some sites (Table 1). In the early work at Rutherglen (Ellington 1986), no yield responses were observed in the dry 1982 season, or at Rutherglen under waterlogged conditions in 1981. Combinations of lime, deep ripping and gypsum gave best yield at both sites in 1983 (data not shown), and direct-drilling reduced the rapid recompaction observed under cultivation. Subsequent experiments further north gave variable results. Angus (1987) measured average yield responses in wheat of 11% at Boorowa and Stockinbingal in 1986, but subsequent experiments at Gidginbung and Temora showed no response. At Temora there was no yield response in canola in 1990 or 1992 despite clear reductions in soil strength and 20-30% increases in the early biomass in the years of ripping, and no response in subsequent wheat crops. Chan et al (2006) found significant yield response in canola on a sodic brown clay (Vertosol) at Grogan (Table 1) and reported significant yield reductions (3.2 to 1.1 t/ha) in wheeled areas compared with non-wheeled areas, but no such effect was observed in wheat. In the dry conditions of 2007, only 2 of the 9 crops showed growth responses to deep ripping and these did not persist to yield, while crops at 3 of the sites had significant yield reductions caused by ripping. The dry

spring conditions and mostly dry subsoils presumably limited crop response to reduced soil strength, and soil water lost in the ripping process presumably contributed to the negative yield responses.

Table 1. Summary of crop response to deep ripping at various sites in south-eastern Australia.

Year	Site	Soil Type	Crop	GSR[B] (May - Nov)	Rip depth /spacing (cm)	Penetrometer resistance (MPa) Control	Rip	Biomass response (%)	Yield control (t/ha)	Yield response (%)	†
1981 (R/G)	Rutherglen	Yellow Sodosol	W	572	40 x 50			yes	1.40	ns	a
1982			W	118				ns	0.80	ns	
1983			W	490		3.10 (0.1)	1.00 (0.1)	-	3.60	+17*	
1981 (R/G)	Boxwood	Red Sodosol	W	463	40 x 50			+108	0.65	+46*	a

1982			W	100				-15	0.20	ns	
1983			W	400		4.00 (0.1)	0.94 (0.1)	-	2.30	+48*	
1986 (R)	Boorowa and Stockinbingal	Sodosol	T	414	40 x 120			yes	4.18	+11*	b
1988 (R)	Gidginbung	Vertosol	W	346	40 x 120			-	2.7	ns	c
1990 (R/G)	Temora	Red Sodosol	C	394	40 x 105	2.75(0.2)	1.15(0.1)	+25*	1.1	ns	d
1991			W	307		-	-	-10*	4.1	ns	
1992 (R/G)			C	349		-	-	+31**	1.6	ns	
1993			W	398		-	-	ns	4.3	ns	
2000 (R)	Grogan	Vertosol	C	407	25 x 35	2.70	0.60	-	2.0	+20*	e
2005 (R)	Bethungra	Kandosol (r)	W	474	30 x 35	2.20(0.30)	1.04(0.10)	ns	7.8	ns	f
2007 (R)	Greenethorpe	Chromosol	C	177	35 x 45	4.15(0.15)	1.41(0.07)	+95*	0.2	ns	f

2007 (R)	Greenethorpe	Chromosol	C	147	35 x 45	-	-	+37	0.2	ns	
2007 (R)	Greenethorpe	Chromosol	W	177	35 x 45	3.26(0.18)	0.61(0.05)	ns	0.2	-30*	
2007 (R/G)	Rand	Sodosol	C	117	25 x 45	2.71(0.26)	1.24(0.25)	ns	2.7 (hay)	-15*	
2007 (R/G)	Lockhart	Vertosol	C	180	35 x 45	-	-	ns	0.4	ns	
2007 (R/G)	Corowa	Chromosol	C	215	25 x 45	4.19(0.11)	1.32(0.17)	-	1.3 (hay)	ns	
2007 (R)	Milvale	Chromosol	C	190	40 x 45	2.52(0.23)	0.57(0.04)	ns	4.2 (hay)	ns	
2007 (R)	Milvale	Chromosol	W	190	40 x 45	2.52(0.23)	0.57(0.04)	ns	5.9 (hay)	ns	
2007 (R)	Tootool	Chromosol	W	208	25 x 45	3.50(0.29)	1.35(0.22)	-	1.6	-12*	
2007 (R)	Morven	Kandosol (y)	C	227	30 x 23	2.5 to 4.0	0.5	ns	1.1	ns	g

[A] Bulk density g/cm^3
[B] In 2007, some crops were cut for hay or harvested prior to the end of November and rainfall falling after harvest has been deducted.
(R/G) indicates the year in which treatments of ripping (R) or ripping+gypsum (R/G) were applied; W=wheat, C=canola, T=triticale, L=lupin
* significant effect of ripping (P<0.05); ** (P<0.01); ns=not significant - not measured; (r) = red; (y) =

yellow
† References: a = Ellington (1986) b= Angus (1987) c=Angus et al (unpublished) d= Cresswell and Kirkegaard (1995)
e= Chan et al (2006) f= Kirkegaard et al (unpublished) g=Moroni et al (unpublished)

The modified Yeomans ripper/injector used in the 2007 experiments was designed and built by Hart Brothers Seeds Junee and made available for experiments by FarmLink Research. Sites for experimental purposes were suggested by Mr Chris Duff (DeltaAgribusiness) with collaborating farmers Mr Rob Taylor, Mr Warrick Hodges (Greenethorpe), Mr David Davidson (Milvale), or by FarmLink Research with Mr Geoff Lane (Lockhart), Mr Roy Hamilton (Rand), Mr Charles Kay (Corowa), and Di and Warrick Holding (Tootool).

Discussion

The paddock survey confirmed the widespread occurrence of high subsurface soil strengths (>2.0MPa) across southern NSW. However, the infrequent yield responses to deep ripping (4 of 23 crops), despite consistent reductions in soil strength to < 1.5 MPa raises questions about identifying responsive soils. In most of the experiments reported here, the argument that re-compaction (as reported by Ellington 1986 and Chan et al 2006) may have reduced the expression of crop response does not hold, as most plot and paddock work used controlled traffic. The yield responsive crops included wheat (3 of 13 crops), canola (1 of 9 crops) and triticale (1 of 1), and all of these occurred on Sodosols and Vertosols in years of 400-500 mm May-October rainfall, suggesting the alleviation of waterlogging on these soil types may have been the major mechanisms involved. Responses did not occur on similar soils types in average seasons (300-400 mm) or on other soils. Canola was more responsive to deep ripping in early vegetative growth (4 of 7 crops measured) than wheat (1 of 8 crops measured), but this rarely persisted to yield. In the very dry year of 2007 (in common with 1982), there was little opportunity for crop response due to severe water stress and frost, and the negative yield responses to ripping at some sites are explicable in terms of water loss associated with ripping. However across years of closer to average rainfall (300-400mm), the failure of crops to respond in early vegetative growth to the consistent reductions in soil strength achieved by ripping (from >2.5 MPa to <1.5 MPa) suggests the commonly quoted value of 2.0 MPa as a critical soil strength considered restrictive may not apply to these soils. No growth response to ripping were observed at sites with strength at 2.75 MPa or less, some sites with 3.0 to 3.3 MPa failed to respond to ripping, while the most responsive sites (Boxwood and Greenethorpe) had soil strength of 4.0 to 4.2 MPa. Roots can penetrate compacted zones in structural cracks or biopores and then proliferate in the structured subsoils at non-sodic sites providing opportunities for compensation where subsoil water or rainfall permits. Thus it is possible that even where compact layers exist, seasonal rainfall patterns in relation to crop growth on relatively permeable soils may not generate yield responses even where early vegetative growth reductions are evident. Economics aside, the current published evidence does not support recommendations to rip soils in south-eastern Australia, except in combination with gypsum on sodic clay soils, where winter waterlogging can cause significant yield reductions in wet seasons. Controlled traffic may best be promoted on the basis of its many other benefits rather than reduced compaction.

References

Angus JF (1987). Effect of nitrogen and ripping on triticale yields. Proc. 13th Southern Cereal Improvement Conference, Condobolin 24-25 March. pp 98. NSW Department of Agriculture.

Chan KY, Oates A, Swan AD, Hayes RC, Dear BS and Peoples MB (2006). Agronomic consequences of tractor wheel compaction on a clay soil. Soil and Tillage Research 89, 13-21.

Crabtree WL (1989) Cereal grain yield responses to deep ripping duplex soils. Australian Journal of Experimental Agriculture 29, 691-694.

Ellington A (1986) Effects of deep ripping, direct drilling gypsum and lime on soils, wheat growth and yield. Soil and Tillage Research 8, 29-49.

Geeves GW, Cresswell HP, Murphy BW, Gessler PE, Chartres CJ, Little IP, Bowman GM (1995). The physical, chemical and morphological properties of soils in the wheat-belt of southern NSW and northern Victoria. NSW CALM/CSIRO Australia Division of Soils Occasional Report.

Hamza MA and Anderson WK (2005). Soil compaction in cropping systems. A review of the nature, causes and possible solutions. Soil and Tillage Research 82, 121-145.

Jarvis R (2000) Deep tillage. In “The Wheat Book:Principles and Practice”. (Eds WK Anderson and JR Garlinge) pp. 185-187. Bulletin 4443. Department of Agriculture, Western Australia.

Kirkegaard JA, So HB and Troedson RJ (1993). Effect of soil compaction on the growth of pigeonpea on clay soils. III. Effect of soil type and water regime on plant response. Soil and Tillage Research 26, 163-178.

Lisson SN, Kirkegaard JA, Robertson MJ and Zwart A (2007). What is limiting canola yield in southern NSW? A diagnosis of causal factors. Australian Journal Experimental Agriculture 47, 1435-1445.

Sadras VO, O’Leary GJ and Roget DK (2005). Crop responses to compacted soil: capture and efficiency in the use of water and radiation. Field Crops Research 91, 131-148.