Decreasing subsoil constraints with topsoil slotting plates

Wayne Parker

Department of Agriculture and Food, 20 Gregory St, Geraldton, WA 6530, wayne.parker@agric.wa.gov.au

Abstract

Subsoil compaction induced by machinery traffic reduces root growth, rooting depth and limits access to moisture and nutrients. Around 70% of soils in the Western Australian wheatbelt have a moderate to high risk of subsoil compaction. Deep ripping with tined implements is the most common way growers rectify subsoil compaction. A deep ripper was specifically constructed to investigate ripping below 450 mm and used in eight trials, at six sites across WA. The ripper has shallow leading tines ripping to 300 mm and rear trailing tines with capacity to rip to 600 mm. Unique to this ripper were topsoil slotting plates attached to the rear tines. A pair of trailing plates, separated by 130 mm, opens a slot in the soil as the tine moves through. A volume of topsoil then falls into the gap created by the plates that are trailing below the soil surface. Results over two years indicate that topsoil slotting plates add to the yield response from deep ripping and provide at least two years of continued positive response in a range of soil types. In 2016 topsoil slotting plates resulted in a 39% yield response, when compared to nil ripping, on grey clay with sodicity at depth. This soil often responds negatively to deep ripping. Further positive responses include 53%, 45% and 17% on loamy yellow sand, sand over gravel duplex and calcareous loamy earth respectively.

Keywords

Deep ripping, subsoil compaction, topsoil slotting.

Introduction

Subsoil compaction induced by machinery traffic reduces root growth, rooting depth and limits access to moisture and nutrients. Around 70% of soils in the Western Australian wheatbelt have a moderate to high risk of subsoil compaction. The penalties in crop yield range from 10 to 30% in around two thirds of years (Peterson 2016). The depth at which compaction occurs is increasing as economies of scale increase the size of farming machinery. There is evidence to show compaction caused by today's machinery occurs at 500 mm on sandy soils (Blackwell et al. 2013).

Deep ripping with tined implements is the most common way growers rectify subsoil compaction. For ripping to be effective the bottom of the tine must penetrate below the bottom of the hardpan. The majority of growers are currently deep ripping to 300 mm. However ripping to 300 mm is no longer providing the yield responses that it once did. Root growth is still impeded at 300 mm by compaction which reduces the capacity of the crop plant to access moisture and withstand heat stress during grain fill (Blackwell et al. 2016).

Subsoil constraints from low sub-surface pH, caused by agricultural practice, and inherent subsoil sodicity, can be rectified with the addition of lime and gypsum ameliorants. Placing these ameliorants below the seeding depth to obtain more efficient responses is logistically challenging and expensive. Western Australia growers in higher rainfall zones have been successfully ameliorating their sandy soils using aggressive tillage including spading or mouldboard ploughing. These machines are limited in their working depth to 300 to 350 mm. These depths are not sufficient to rectify the subsoil compaction occurring below 400 mm.

There is an opportunity to move topsoil, and surface-applied ameliorants, into the subsoil using topsoil slotting plates when deep ripping. A pair of trailing plates, separated by up to 130 mm, is attached to the rear of the ripping tine, and these plates open up a slot in the soil as the tine moves through. A volume of topsoil falls into the gap created by the trailing plates that are working below the soil surface. Surface soil with higher organic levels, crop residue and applied soil ameliorants are now mixed through a narrow channel to the depth of the rip-line in the profile. These channels allow plant roots to negate areas of constraint and access moisture and nutrients deeper in the soil. In following years, ripping can be offset to open more channels. Topsoil slotting plates can provide some of the benefits of the more expensive amelioration treatments, mouldboard ploughing, spading, for a range of soil types in the grain belt.

In 2015 trials were instigated to investigate the benefits of deep ripping with topsoil slotting across eight different soil types at six separate sites throughout the Western Australian wheatbelt. In this research we investigate how the use of slotting plates, that result in topsoil and surface organic material falling into the ripped slot, affect crop yield responses and the longevity of the response, under controlled traffic farming.

Methods

A deep ripper used in these eight trials was specifically constructed to investigate ripping below 450 mm. It had parabolic shallow leading tines from a Grizzly Deep Digger™, and deeper following Agrowplow® straight leg tines, with the capacity to rip to 600 mm. This ripper had a ripping width of 3.5 m. Paired topsoil slotting plates were attached to the deeper following tines. Plates were 28cm long and 43.5 cm deep, and separated by 130 mm. Once the site was ripped the trial is sown, managed and harvested, by the grower each season using the grower's broad scale machinery. Trials are managed within the controlled traffic system of the individual grower to eliminate re-compaction through machinery traffic.

Ripping treatments applied to the site were dictated by the soil type. Each site has a ripping treatment of nil and 300 mm. Deeper ripping then varied between sites as it was not physically possible to rip to 600 mm at every site. Ripping occurred in the first season only. Results presented in Table 1 were analysed using a simple linear mixed model, REML, to compare incomplete factorial layouts of the treatments.

Table 1. Crop yields (t/ha) in 2016 from deep ripping with and without topsoil slotting plates (TS) in 2015, on controlled traffic cropping land. The LSD (P=0.1) is presented, with * indicating differences compared to the nil treatment.

Site	Soil type	Species	Ripping	2016	LSD
Binnu Swale	Loamy yellow sand	Lupin	Nil	2.05	0.36
			550	2.50*	
			550 + TS	1.77	
Binnu Dune	Pale yellow sand	Lupin	Nil	1.00	0.19
			550	1.18	
			550 + TS	1.00	
Moora	Loamy yellow sand	Barley	Nil	1.43	0.3
			550	1.99*	
			550 + TS	2.19*	
Munglinup	Sand over gravel duplex	Barley	Nil	2.19	0.3
			300	2.70*	
			600	3.03*	
			600 + TS	3.17*	
Broomehill	Sandy loam over clay	Barley	Nil	2.68	NS
			300	2.53	
			550	2.91	
			550 + TS	3.10	
Beacon York gum	Deep sandy duplex	Wheat	Nil	1.60	0.27
			450	1.21*	
			450 + TS	1.45	
Beacon Morrel	Calcareous loamy earth	Wheat	Nil	1.79	0.31
			450	1.81	
			450 + TS	2.10*	
Ongerup	Gritty grey clay	Barley	Nil	2.77	0.65
			450	3.18	
			450 + TS	3.85*	

Results

Binnu Swale

Unlike 2015, where yield responses to deeper ripping in wheat were around 1 t/ha, the 2016 lupin yields showed little response or negative responses to deeper ripping or topsoil slotting. The negative response of lupins to deep ripping and topsoil slotting was also observed at a nearby sandplain trial site south of Binnu in 2016 (B. Isbister, unpublished data). Plant emergence was 55 plants/m^2 and was similar across all treatments. Anthesis biomass of the plants in the topsoil slotted plots was significantly lower than other treatments in spite of adequate plant emergence.

Soil strength measurements were measured for topsoil-slotted plots using a RIMIK digital cone penetrometer in moist conditions. The data indicate soil strengths above 2 MPa beginning at 200 mm depth between the tines. The topsoil slotting plates re-compacted this soil between the tines while leaving the rip line soft and accessible. In comparison the 550 mm ripping without topsoil slotting plates reaches 2 MPa between 520 and 540mm. Further penetrometer testing is required to isolate the impact of the slotting plate on soil strength between the tines. For ripping depths of 300 and 550 mm, lupin yields did not differ from the Nil ripping treatment. Ripping to 550 mm with topsoil slotting reduced biomass while increasing seed size. However, the highest wheat yield in 2015 was from topsoil slotted plots which yielded an additional 1.8t/ha over Nil treatments.

Binnu Dune

The addition of topsoil slotting plates had no impact on lupin yields in 2016 (Table 1). Similar soil strength patterns were observed when comparing the Dune site with the Swale site. The soil strength of topsoil slotting plots between the rip-lines increased rapidly from a shallow depth. In the dune soil with 550 mm topsoil slotting the strength between tines reaches 2 MPa at 160 mm and 3MPa at 200 mm. There was no ripping treatment or topsoil slotting influence on biomass or seed weight for lupins in 2016.

Moora

Ripping to 550 mm with topsoil slotting increased barley yield by 0.2 t/ha above the 0.56 t/ha for the ripping treatment. Some unreplicated, preliminary canopy temperature measurements using infrared temperature loggers indicated temperature differences between Nil ripping and deep ripped to 550mm with topsoil slotting treatments. Logistics dictated that only one plot of deep ripped + TS and one Nil treatment was able to be measured. The plants in the deep ripped soil with top-soil slotting were 0.59°C (± 0.36) cooler than those in the un-ripped soil. Such temperature differences indicate the plants in the deep ripped + TS soil had better access to soil moisture. There were trends of greater biomass and head number in the 550 mm topsoil slotting treatment, but fewer grains per head, when compared to the Nil treatment.

Munglinup

Record rainfall at this site saw a number of plots submerged or showing signs of waterlogging during the 2016 season. Increasing ripping depth and topsoil slotting increased yield response. The soil strength measurements at Munglinup did not replicate observations of Binnu and Moora sites. At Munglinup soil strength between the tines of the topsoil slotted plots did not increase above 2 MPa until the depth of 520 mm was reached. Correspondingly, the score for number of roots in the soil negatively correlated with the penetrometer measurements (r^2=0.57). Ripping to 600 mm and the 600 mm + TS produced significantly more roots deeper in the profile than Nil treatments, though not significantly different from each other. At this site it appears ripping provided a drainage benefit as root number increased with ripping and ripping depth.

Broomehill

The site has different soil types occurring across the trial site which resulted in large variations in yields within treatments. Significant yield responses did not occur and further analysis is being undertaken. Deeper ripping to 550 mm tended to provide positive yield response. Gravel stones present made penetrometer readings difficult to take. The penetrometer data indicated some loosening of the soil in the ripping to 550 mm treatment. Efficacy of the topsoil slotting plates was reduced as hardpan, gravel and reduced machine hydraulic pressure combined to lift tines out of the ground irregularly across the trial site.

Beacon York Gum

Both Beacon sites were impacted by harvest compaction during the 2015 harvest and it is likely that this led to a reduction in yield response. This soil type has not responded positively to deep ripping. Yield was negatively influenced by ripping without topsoil slotting. However, ripping to 450 mm with topsoil slotting did not significantly reduce yield. The penetrometer data, sampled outside of harvest compaction areas, indicate the ripped soil has returned to strength levels at depth, equivalent to those of the un-ripped treatment. Soil chemistry and particle size distribution in the sub-surface is likely to have increased the soil strength after the disturbance during ripping.

Beacon Morrel
Ripping to 450 mm with topsoil slotting has resulted in a positive yield response in 2016. Improved yields with topsoil slotting also occurred in 2015. There were interactions between the topsoil buried to depth and the high sodium subsoil that require further investigation. Unlike the 2015 season, there was no discernible influence in 2016 of treatments on screenings, seed weight or grain quality. Frost may have confounded results as an average frost-induced sterility of 22% occurred across all plots.

Ongerup
The soil at this site is sodic and dispersive below 300 mm. Topsoil slotting provided 600 kg/ha more yield than deep ripping alone. A mild season finish, large volumes of early rainfall and frost had a large influence on the results of the trial. The sand over clay duplex soil, suffered from water inundation through May and early June. A dry period during July allowed drainage and water infiltration to occur. The waterlogging response of the crop was not sufficient to give visual symptoms. Deep ripping does assist drainage and may have increased the volume of water in the subsoil for biomass production and grain fill late in the season. The mild spring combined with deeper access to soil moisture enabled plants to recover from frost with late tillers providing grain that would not have filled in a season with a warmer finish.

Conclusion
Topsoil slotting adds to the yield response from deep ripping and is able to provide at least two years of positive response in a range of soil types. It increased crop yields in 2016 at 5 of the 8 sites in this study.
A thorough understanding of the subsoil is important to maximise the value of deep ripping. These trials, and others (Parker et al. 2017), have shown positive yield responses in sodic soils when topsoil, with higher organic matter levels, and surface crop residue was able to fall into the rip-lines. Topsoil slotting plates should be fitted if ripping these soils. There is some evidence from grower experience that altering the topsoil slotting plate orientation can increase the effectiveness in some soils and this is an area of further investigation.
On yellow sand at Binnu and Moora the topsoil slotting has caused a re-compaction of soil between the tines. The 50 cm tine spacing means that there is 37 cm of sub-surface soil between the plates in adjacent rip-lines. It would appear the current shape of slotting plate is not sufficient to allow for soil breakout between plates and so the inter-row soil is being compressed as the plates pass. Soil particle size distribution, moisture conditions, depth of ripping, depth of topsoil slotting plate, width between plates, plate angle will determine the degree to which this occurs. Design of topsoil slotting plates requires further investigation to ensure that inter row compaction is minimised while retaining the capacity to bury crop residue. The addition of winged points to the tine may be sufficient to increase breakout and loosen a greater volume of soil for the plates to pass through.

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