INCLUSION RIPPING TECHNOLOGY

FACT SHEET

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

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Understanding passive inclusion ripping

Photo: Jack Desbiolles

Photo 1: Inclusion ripping in deep sandy soils has the potential to boost the crop response beyond deep ripping alone.

KEY POINTS

- Inclusion ripping technology is designed to drop topsoil deep into the rip-line during the process of subsoil tillage.
- Adding inclusion plates to a deep ripper significantly increases the draught requirement, but this may be minimised by using improved ripper point and plate combinations.
- The depth of the plate bottom edge has the greatest impact on the draught force.
- The plate design and settings, ripping speed, timing of operation, soil type and moisture are key factors driving the inclusion performance.
- High ripping speed significantly reduces the amount of topsoil inclusion, but this can be mitigated by increasing the length of the plate.
- The operating depth of the top edge of the plate relative to the soil surface determines the thickness of topsoil layer being included, but the impact of soil upheaval while ripping needs to be factored in.
- Computer simulation is a powerful tool to help optimise solutions for passive inclusion and ultimately for more selective active inclusion systems.

Introduction

This fact sheet summarises the latest on the mechanics of topsoil inclusion following recent and ongoing research in South Australia, which built on the pioneering development of topsoil slotting technology in Western Australia in the early-mid 2010s (Parker, 2017). Implications for inclusion plate design and operational settings are explored.

'Inclusion rippers' refer to subsoiling or deep tillage implements fitted with inclusion plates. These plates consist of a braced pair of flat plates bolted behind a deep ripping tyne and spaced to form side-shields (Photo 2, left). During deep ripping in loose sandy soils, the cavity

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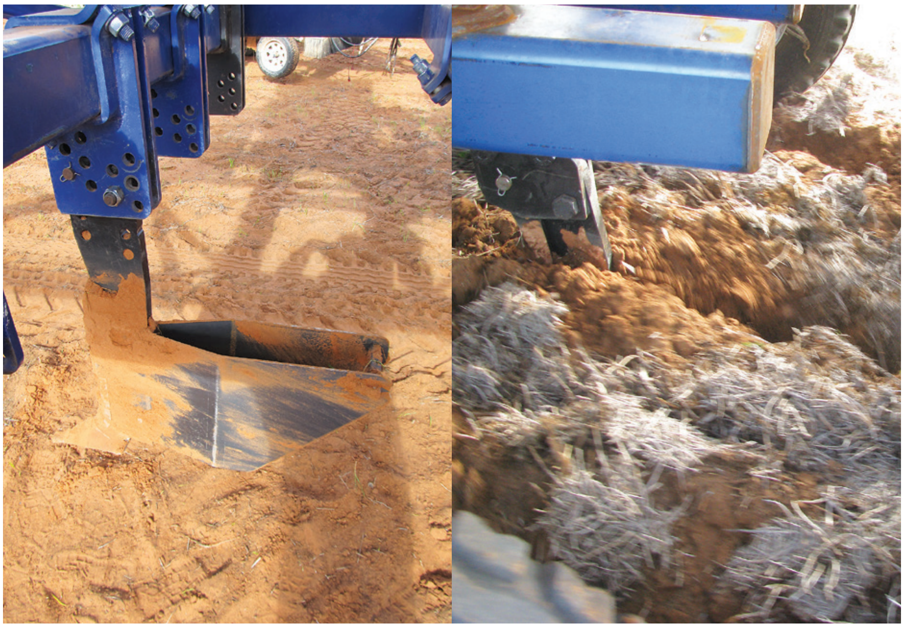
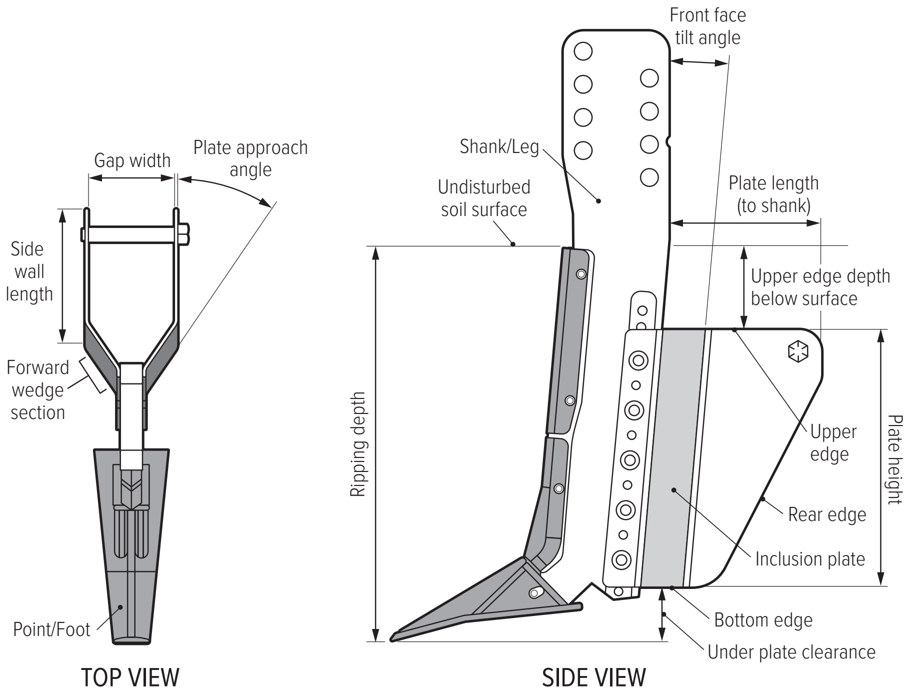
Photo 2: High-capacity inclusion plate (600 millimetres [mm] length to shank) fitted to a narrow shank subsoiler tyne (left) and the topsoil backfilling process while inclusion ripping to 600mm depth (right).



Photos: Jack Desbiolles

Figure 1: Parameters of ripper tyne and inclusion plate geometry.



Source: UniSA

forced open by the tyne is expanded by the plates, which allows large quantities of topsoil to fall over their upper edges (Photo 2, right) deep within the loosened soil profile. Figure 1 outlines the terminology of inclusion plate geometry.

The aim of inclusion plates is to create a column of improved soil down the profile in subsoil that has been previously constrained by any number of limitations to root growth, for example high strength, poor structure, nutrient deficiencies, acidity or alkalinity. Inclusion ripping often results in additional crop biomass and grain yield when compared with deep ripping alone, and with longer-lasting benefits as suggested in recent research (McBeath et al., 2022).

This is particularly the case in stratified sandy soils when the topsoil is rich in organic matter, mineral nutrients and/or amendments (for example lime or manure). Inclusion of these topsoils improves depleted sublayers, the growth of deep roots and uptake of moisture and nutrients.

Mechanics of inclusion

A backfilling process or inclusion happens naturally behind a tillage tyne, whereby the loosened, flowable topsoil falls into the cavity left by the tyne prior to closing. This passive inclusion process can be controlled and maximised by adding inclusion plates fitted behind narrow shank tynes.

The inclusion process starts with the soil directly above the upper edge of an inclusion plate falling over the edge and dragging layers above it into the cavity. The inclusion outcome is affected by plate design, paddock operational factors and soil properties such as flowability. Inclusion is most effective in dry sandy soils. Soil cohesion in loams or clay reduces flowability, and pre-tilling the top layer may be necessary to create soil tilth, reduce moisture and improve flow.

The impacts of plate length, upper-edge depth and under-plate clearance on inclusion performance have been investigated via computer simulations using Discrete Element Method (DEM) modelling (GRDC 2019) and were validated in the SA Mallee during 2019. The DEM simulation can be used to track and visualise soil particle movement and final topsoil inclusion outcomes.

Figure 2 illustrates a ripper tyne with a high-capacity inclusion plate during three stages of moving through soil layers represented by different colours. The inclusion outcome in the bottom diagram (Figure 2c) shows how the inclusion space is filled with particles from various layers above. The included soil contains layers initially located below the top edge of the plate (for example green and yellow), due to the upheaval associated with the loosening process (Figure 2b).

The gradational mix of coloured particles within the inclusion space suggests that inclusion occurs mainly as a 'full layer collapse' over the plate edge and not as a 'surface-first' shedding process, which is consistent with paddock observations.

The depth of the top edge of the plate relative to the surface determines the

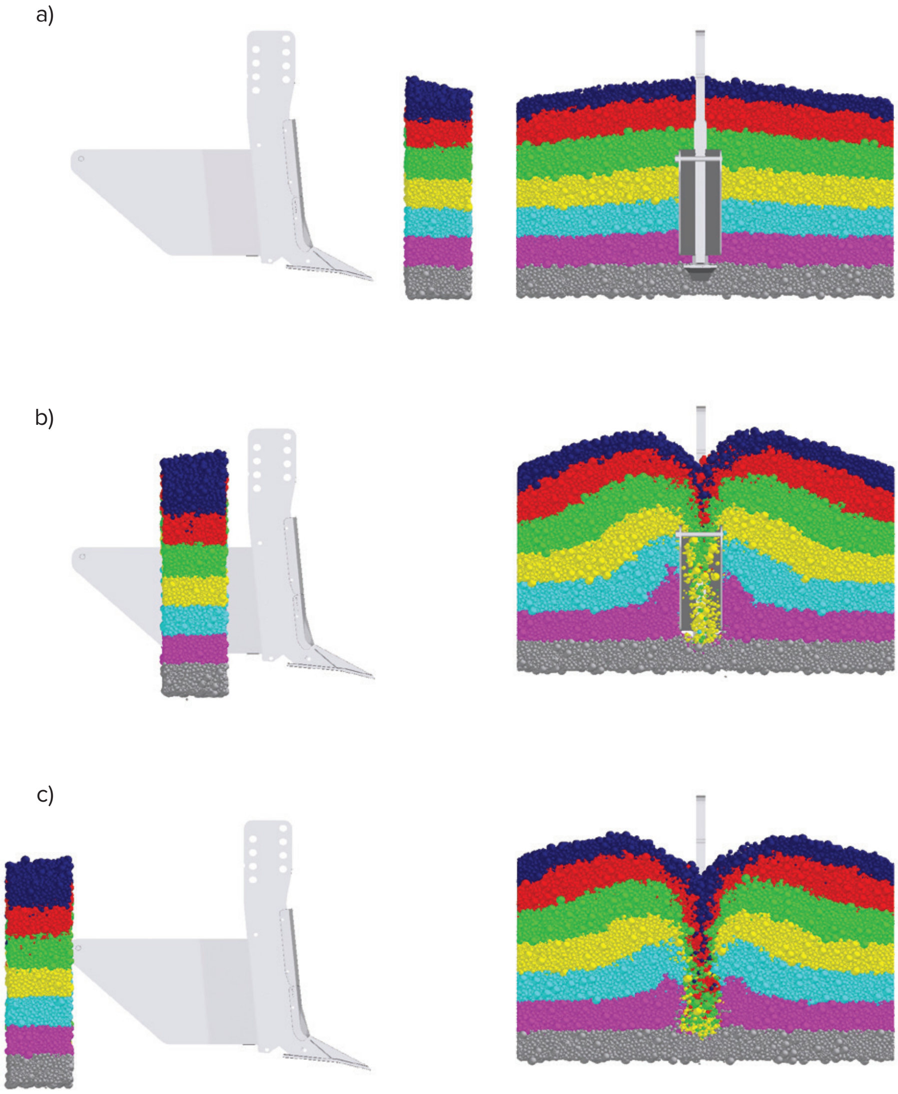
Figure 2: Computer simulations of the process of topsoil inclusion with a ripper tyne and inclusion plate, tracking the movement of soil layers over a 600mm deep profile.

a) Soil profile with layers in their original locations in early stages of loosening by the tyne.

b) Fully upheaved soil profile during loosening with additional sublayers lifted above the plate edges in the early stages of inclusion.

c) Inclusion outcome showing a gradational mix of soil layer particles.

NB: The simulation reflects high-capacity inclusion plates (390mm H x 600mm L x 131mm W) operated at 4km/h in a dry sandy soil profile with good flow properties.



Source: UniSA (software: Altair EDEM™)

thickness of topsoil layer included. This implies that shallow settings are required to maximise the inclusion of topsoils containing top-dressed amendments near the soil surface such as lime.

However, shallow settings also minimise the soil volume eligible for natural inclusion, and are therefore better suited to an active inclusion system (see last section).

Quantifying inclusion performance

The proportion of each topsoil layer shown within the inclusion space (Figure 2c) can also be quantified by DEM simulations for a more detailed analysis of the impacts of plate design, soil conditions and operational settings. This supports an optimisation process for reliable inclusion outcomes.

Figure 3 illustrates in a colour-coded form the relative quantities of the original layers within the inclusion space in 50mm increments down the profile. The three graphs contrast the inclusion outcomes of a control ripper tyne with no inclusion plate operating at 4km/h (Figure 3a), a baseline commercial inclusion plate operating at 7km/h (Figure 3b) and a high-capacity inclusion plate operating at 4km/h (Figure 3c).

Figure 3a shows minimal inclusion achieved by the tyne alone in both quantity and depth below origin, while layers have also been pushed upward from soil heaving during loosening. In comparison, the installation of a commercial baseline inclusion plate (Figure 3b) was able to include significantly greater proportions of particles in the adjacent layers immediately below the depth of origin, but only small quantities were able to reach down to 200mm below the depth of origin.

The inclusion outcome was significantly improved by using a high-capacity plate combined with a slower ripping speed (Figure 3c), which maximised the proportions of 0 to 150mm layer particles included throughout the profile, reaching near-full depth. The inclusion space mainly contained particles originating from the top four layers, rather consistently with depth. Specifically, the high-capacity plate operatiing at 4km/h resulted in the top 250mm soil layers being successfully included down to 550mm depth and forming 60 to 75 per cent of the soil present within the 350 to 550mm depth zone, unlike the commercial inclusion plate operating at the faster speed, which included negligible quantities in that same depth zone.

These simulations show the critical importance of matching the top-edge length to the ripping speed to achieve the intended inclusion outcome, and the challenge of successfully including a large quantity of surface soil deep into the profile. The drier the topsoil, the greater the flowability and the more effective the inclusion process.

The impact of moist sublayers on optimum plate depth and on the effectiveness of dry surface layer selection for inclusion requires further investigation.

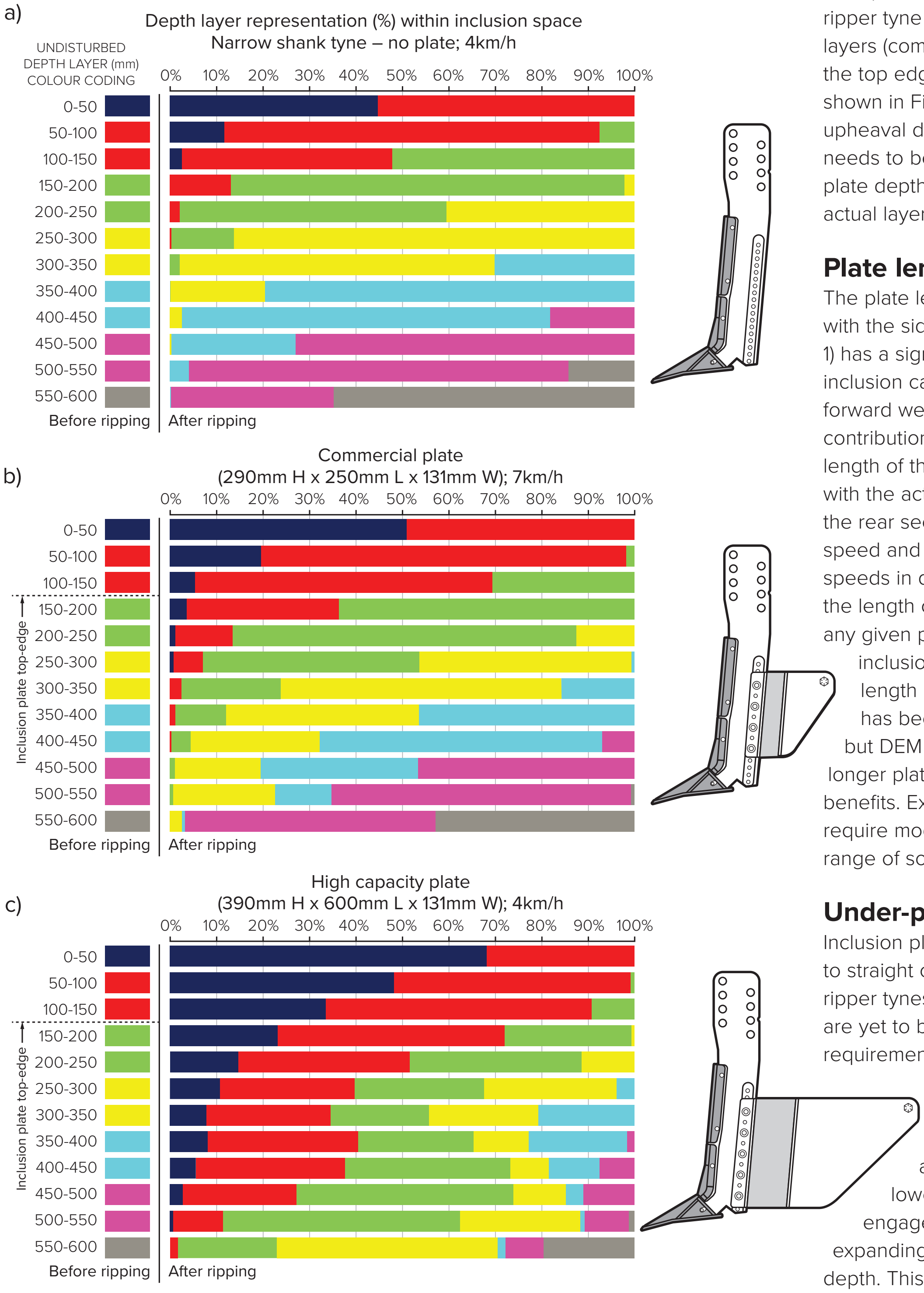
Figure 3: Simulation-based inclusion performance for three contrasting tynes operating at 600mm depth in a dry flowable soil.

a) Control ripper tyne with no inclusion plate.

b) Typical commercial size plate (290mm H x 250mm L x 131mm W) operated at 7km/h.

c) High-capacity research plate (390mm H x 600mm L x 131mm W) operated at 4km/h.

NB: % values represent the make-up proportions of particles by layer of origin, with the original undisturbed profile outlined on the left. Dark blue and red particles originate from layers initially targeted for inclusion.



Source: UniSA

Optimising passive inclusion set-up

Top-edge depth setting

In practice, the plate upper-edge is commonly set in the range of 100 to 150mm below the undisturbed soil surface. However, the effect of the soil upheaval during loosening by the ripper tyne additionally brings deeper layers (commonly 150 to 200mm) above the top edge of the inclusion plate as shown in Figure 2b. The amount of upheaval during the ripping process needs to be factored into the optimum plate depth setting, relative to the actual layer targeted for inclusion.

Plate length

The plate length (to shank) combined with the side-wall length (Figure 1) has a significant effect on the inclusion capacity at speed, while the forward wedge section has the least contribution. In practice, the whole length of the plate is not fully functional, with the active part concentrated over the rear section depending on ripping speed and topsoil flowability. Slow speeds in dry flowable soils maximise the length of the active portion of any given plate and promote greater inclusion. To date, the plate length used in paddock research has been limited to 600mm, but DEM simulations suggest that longer plates may provide additional benefits. Extra-long plates are likely to require modifications to manage the range of soil forces encountered.

Under-plate clearance

Inclusion plates are commonly added to straight or parabolic narrow shank ripper tynes, but such combinations are yet to be optimised for draught requirements. A deep setting of the plate reduces the under-plate clearance above the ripping point, and typically forces the lower section of the plate to engage with undisturbed soil, expanding the furrow opening at depth. This engagement greatly impacts draught force and is associated with high wear and potentially deep layer compaction and smearing.

Figure 4 shows examples of increased draught across a range of inclusion plates on a deep sandy soil. The extent of ripper tyne draught increase (+36 to 75 per cent under the experimental conditions) was directly associated with the reduction of under-plate clearance (from 181 to 31mm).

The same dataset confirms that with a constant bottom-edge setting, a longer plate does not require significantly more draught.

Inclusion gap width

The gap width of large capacity inclusion plates used in field-tests ranged from between 131 and 185mm with a 600mm length to shank. In comparison, the width of commercial plates fluctuates between 80 and 160mm but associated with short lengths in the range of 250 to 300mm.

Under dry, flowable soil conditions, the gap width is usually optimised to mitigate blockage risks from surface residue and weeds. In cloddy soil conditions, inclusion capacity and reliability are both improved with a wide plate gap.

At similar plate height and under-plate clearance settings, a wide inclusion plate increases draught due to greater interaction with the lower furrow and increases soil surface roughness via greater bulldozing of the loosened profile.

Plate strength considerations

Significant soil forces act on the forward wedge section, subjecting the plates to high wear. High-strength steel plates reduce wear rate and the addition of an inner brace helps maintain the gap width during operation. Design solutions should integrate the inner brace within the forward wedge section to keep the active rear portion of the plate as unrestricted as possible. This ensures that the uniformity of the backfilling process is not interfered with and reduces the risks of blockage.

Plate strength and draught issues become less critical when inclusion plates are set with a high underside clearance and where the ripping point incorporates wings to sufficiently broaden the lower parts of the furrow and minimise stress on the plates. Some commercial solutions include wear plates bolted over the forward wedge section, also strengthening the inclusion plates (Photo 3).

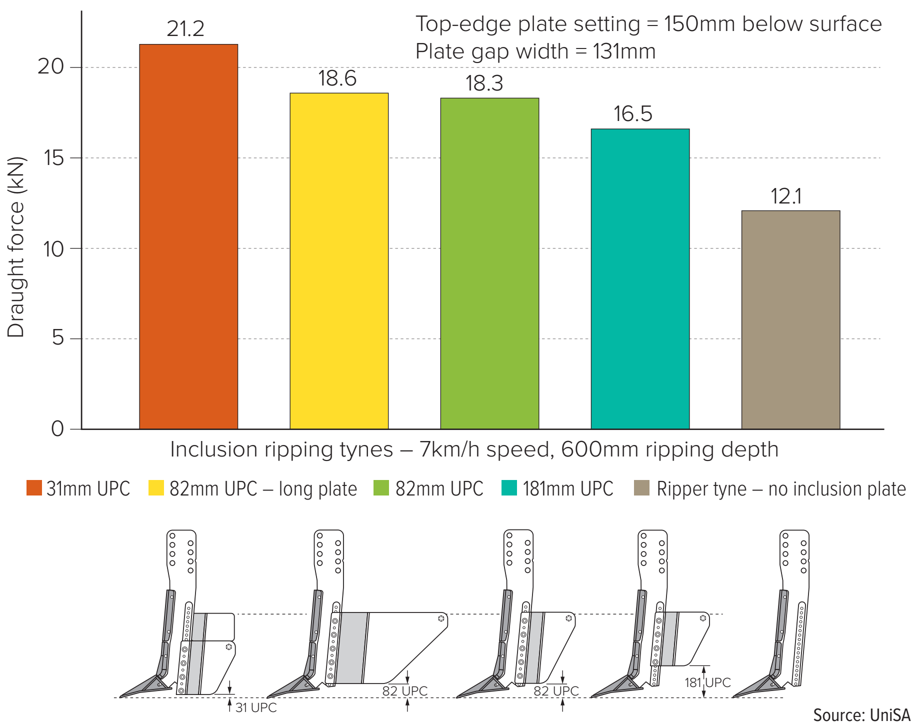
In wet and heavy textured soils, excessive soil build-up over the plate surface is a potential issue, which is yet to be successfully mitigated. Low adhesion material and slatted designs may minimise draught penalties and maintain inclusion performance.

Research opportunities

Ongoing research continues to shed light on the mechanics of inclusion. For instance, the impact of a vertical rear-edge (square plate) rather than tapered, and a downward sloping top-edge as seen on some commercial inclusion plates are being explored (Photo 3). There is also a need to optimise designs to promote soil layer mixing – rather than banding – which may be an important consideration for amendments such as lime and gypsum. More research on the different combinations of ripper points and inclusion plates is required to find the most energy-efficient combinations for high-capacity inclusion. Opportunities also exist to optimise a two-stage inclusion process, whereby similar inclusion outcomes may be achieved with more compact plates.

The limited control over the layer included and depth of inclusion with a passive inclusion process underpins a rising interest in active inclusion systems. For example, the use of skimmer discs can positively direct large quantities of the topsoil down into the inclusion space. Research is planned to further develop active inclusion solutions, following some early proof-of-concept work to date (Photo 4).

Figure 4: Effect of under-plate clearance (UPC) on inclusion ripping tyne draught (Caliph, SA Mallee, 2019, deep red sand, 1.47 to 1.53 grams per cubed centimetre [g/cm³] dry bulk density at 0.2 to 0.6 metres [m] depth).



Source: UniSA

Photo 3: Commercial inclusion plates exist in many shapes and sizes and evaluation using computer simulation can help guide their selection and settings for best results in the paddock.

Photo: Jack Desbiolles

Photo 4: Proof-of-concept active inclusion system (top) is able to maximise inclusion capacity (bottom-left) and achieve a consolidated and levelled seeder-ready finish (bottom-right).

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GRDC CODES

CSP1606-008RMX (CSP00203)

DAW1407-004RTX (DAW00243)

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USEFUL RESOURCES

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