

Deep Ripping Efficiency Considerations (Pt. 1)

Sub-line: Effects of tyne design on soil loosening efficiency in Mallee sandy soils.

Introduction

Deep ripping has become widespread on Australian cropping farms in recent years. Deep ripping tynes exist in many different shapes and it is useful for farmers to know the impacts of tyne design and features on the energy efficiency and loosening effectiveness of deep ripping. This factsheet outlines some of the findings from recent research conducted in Mallee deep sandy soils using a selection of five narrow shank ripper tynes, with and without wings, and five delving/mixing ripper tines (Image 1).



Image 1: Research conducted over the last 2 years in Mallee sandy soils used a research ripper frame with draft force measuring capability to quantify the impacts of a selection of deep ripping tyne designs on soil loosening efficiencies (Image: University of South Australia)

Key Points:

Recent field testing of two groups of 5 deep ripping tynes in SA Mallee sandy soils showed that:

- Ripping depth is the most important factor affecting narrow shank tyne performance, measuring a 2.4-fold draft increase and a significant reduction in soil loosening efficiency from 400 to 600 mm depth.
- Ripping at 7 km/h, relative to 4 km/h, increased draft by 15-18% (narrow shank tynes) and 26-42% (delving/mixing tynes) and more than doubled drawbar power.
- Tyne design accounted for approximately 25% range in draft about the average, but more validation work is required to confirm trends across tynes.
- The delving/mixing ripper tynes operating at 600mm depth required similar draft to narrow shank tynes at 4 km/h but with 20% greater loosening capacity. They required 13% more draft at 7 km/h.
- Adding wings to narrow shank ripper tynes greatly improved the soil loosening efficiency.
- Operating in overly wet sandy soil condition reduced tyne draft but also its loosening capacity, overall reducing its efficiency.
- The measured draft forces in this research can assist with estimating tractor power requirement for deep ripping Mallee sands. A Part 2 factsheet will address the impact of tyne spacing and layout configurations on deep ripping performance.

Deep ripping performance parameters

The following parameters can be used to assess the performance of a deep ripper tyne:

- **Draft force** (D in kN units, NB: 1 kN $\approx$ 100 kgf) or the drawbar pull of a deep ripper which needs to be matched with adequate pulling capacity of a tractor. Single tyne draft is best used when assessing differences between tyne designs, while the draft of two adjacent tynes in a sub-unit

layout is subject to beneficial interaction function of tyne spacing. Note: The rolling resistance acting on implement depth gauging wheels is additional to draft forces acting on the ripper tynes.

- **Drawbar power** (P_{DB} in kW units, NB: 1 kW $\approx$ 1.34 HP) which is the tractor power required at the implement drawbar, calculated as: ripper draft force (kN) x forward speed (m/s). The corresponding tractor engine power can be obtained by dividing drawbar power with a tractive efficiency factor and internal transmission losses. Tractive efficiency factors for larger tractors operating in tilled and soft soil conditions, relevant to many sandy soils, are in the order of 65-75% (See Figure 1).
- **Tyne loosening capacity** (C_T in %) is a relative measure of furrow cross-sectional area loosened by a single ripper tyne operating at a depth d and expressed as a proportion (%) of the tyne 'operating space' within an implement layout. For this, we arbitrarily assume an implement where tine spacing equals operating depth [i.e. tyne operating space = $d \times d$]. The higher the C_T value, the greater the ability of a specific tyne design to loosen its operating space within an implement.
- **Specific draft resistance** (D_s in kN/m²) is an energy efficiency parameter, of draft requirement per unit of loosened furrow cross-sectional area, whereby higher efficiency is shown by lower values. D_s of a single tyne or of two adjacent tynes interacting within an implement sub-unit layout can be considered.

Draft and drawbar power are useful energy parameters for optimising effective tractor power use in deep ripping operations, while the tyne loosening capacity is valuable when seeking to maximise the extent of soil loosening at depth via tyne design and layout. The efficiencies of these parameters combine into the specific draft resistance, commonly used as a benchmark performance indicator.

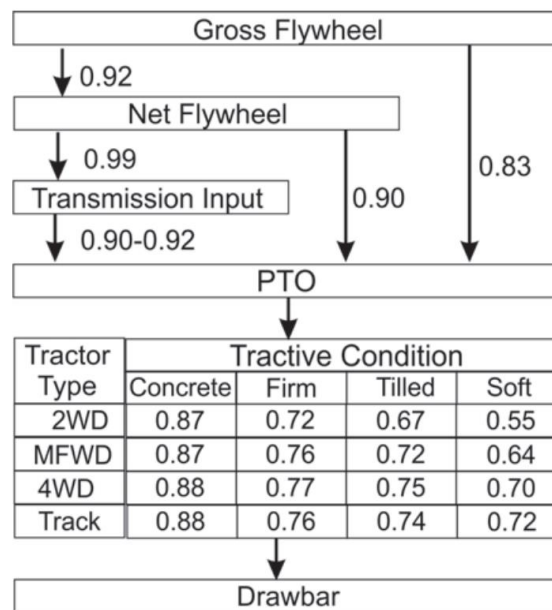


Figure 1: Example efficiency factors involved in power transmission between tractor engine and drawbar (source: ASABE, 2015)

Impact of operating depth and speed on draft

i) Narrow shank tynes

Narrow shank ripper tynes are designed for low surface disturbance soil profile loosening with limited or no sub-layer delving/mixing ability. A selection (see Image 2) of single tynes was compared when operating at 400 mm and 600 mm depth and two speeds (4 and 7 km/h) in moist Mallee deep sandy soil conditions.



Image 2: Narrow shank ripper tynes evaluated in Mallee trials (Images: University of South Australia)

L to R: Agrowplow #9 shank with 50/80mm wide GP blade (100mm lift), Grizzly Digger parabolic shank with standard 60mm wide blade and shin (80mm lift), He-Va Subtiller shank with 35/120 mm wide blade (50mm lift), Tilco Ag Systems rigid shank with standard 70/110mm wide blade (20mm lift) and Williamson-Agri Michel curved shank with offset 50mm wide blade (115mm lift).

Overall, operating depth has the most significant impact on single tyne draft with an average of 145% greater draft (= extra 8 to 9 kN) when increasing depth from 400 to 600 mm (i.e. a 50% depth increase) irrespective of speed – see Figure 2. This impact is greater than the expected square-law rule-of-thumb that commonly applies to the effect of depth (i.e. +50% depth → +125% draft), which likely indicates the 600 mm depth in deep moist sand may lie below the critical depth of these narrow shank tyne designs. Deep ripper should always operate above critical depth to minimise draft, wear and avoid sublayer compaction (see GRDC-2022).

These results point to the critical importance of restricting the depth of ripping to the constrained target zone when addressing excessive soil strength within the profile. Tine designs incorporating wings achieve a wider furrow loosening at depth and are a way to minimise the extra depth of ripping required to loosen the profile effectively between rip-lines (See section on benefits of adding wings).

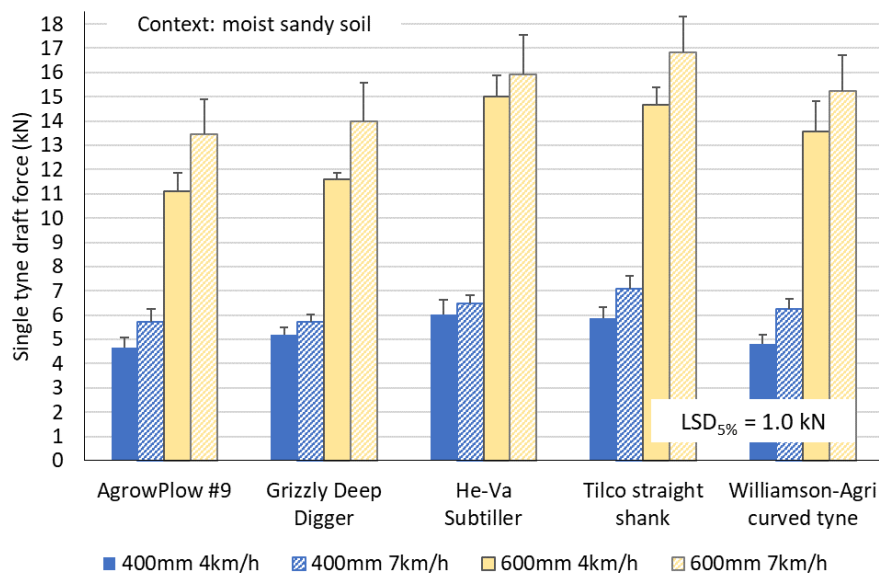


Figure 2: Narrow shank tyne draft values in moist sandy soil

Error bars = 1 standard error of the mean (n=4)

In contrast, a 75% faster ripping speed - from 4 to 7 km/h - increased single tyne draft values by only 15-18% (= +1 to 2 kN on average). While, **drawbar power** virtually doubled from 4 to 7 km/h, on average from 5.9 to 12.2 kW/tyne at 400 mm depth, and from 14.6 to 29.3 kW/tyne at 600 mm depth- see Table 1. These results highlight the tractor power penalty associated with higher ripping speed and the

opportunity to optimise machine width at a lower speed within the tractive capability of the tractor, to reduce power and fuel consumption per ha.

ii) Delving/mixing tynes

Deep ripping tynes with inclined faceplates create high disturbance soil profile loosening and are designed to achieve sub-layer delving to cover the surface layer and achieve some amount of mixing in the furrow backfilling process. A selection was compared as single tynes operating at 600 mm depth and two speeds (4 and 7 km/h) in moist Mallee sandy soil conditions (see Image 3). These tynes differed slightly in rake angle, face plate width and shape, as well as accessories (e.g. knife splitter, winglets).



Image 3: Delving/mixing ripper tynes evaluated in Mallee trials (Images: University of South Australia)

L to R: Agrowplow delving shank with 93mm wide plate & wedge splitter, Bednar Terraland 70mm wide Active-Mix tyne fitted with 150mm wide top-plate, Dondi 800-series with 100/80mm wide tip with 330mm wide winglets & knife splitter, He-Va Subtiller shank with 35mm wide tip & 80mm wide steep face plate, and Leinert 65/110mm wide tip & 130mm wide cupped delving plate.

At the lower speed (4 km/h), the draft values of delving/mixing or narrow shank tynes were similar. Conversely, at the higher operating speed (7 km/h), the draft of delving mixing tynes reached approximately 13% or 2 kN higher at the 7 km/h speed. The impact of speed on the draft force of delving/mixing tynes was therefore more significant (extra 26-42% or +3.5-4.5 kN) due to the quantity of upward soil movement generated in their delving function— see Figure 3.

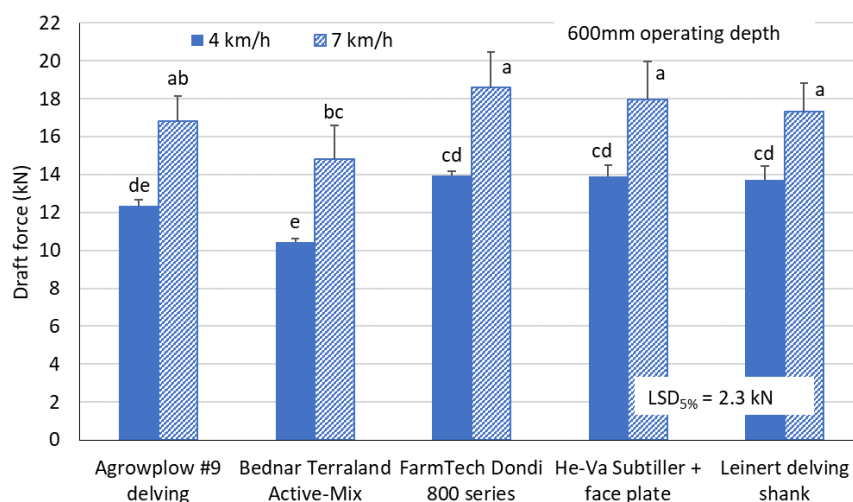


Figure 3: Delving/mixing tyne draft values in moist sandy soil context (4 & 7 km/h, 600 mm depth) ; Error bars = 1 std error of the means (n=4), different letters indicate significant differences at the 5% risk probability level.

The drawbar power ranged between 11.6-15.5 kW/tyne at 4km/h and 28.8-36.2 kW/tyne at 7 km/h - see Table 1a. This draft increase at 7 km/h resulted in more than doubling (+132%) the drawbar power requirement with an additional 19 kW per tyne on average, making faster delving/mixing ripping operations significantly more costly.

Table 1a and Figure 1 can be used together to estimate tractor engine power requirements for deep ripping as shown in Table 1b. For instance, a deep ripper with 7 narrow shank tynes operating at 600 mm depth and 7 km/h would need 342-428 kW engine power on a 4WD tractor under these experimental conditions.

Table 1a: Range in drawbar power requirement (kW/tyne) measured for selections of deep ripping single tynes evaluated in moist deep sand conditions* (Parrakie SA, 2023).

Depth / Speed	4 km/h	7 km/h
Narrow shank ripper tynes (Image 2)		
400 mm	5.2-6.7 kW	11.1-13.8 kW
600 mm	12.3-16.7 kW	26.2-32.7 kW
Delving/mixing ripper tynes (Image 3)		
600 mm	11.6-15.5 kW	28.8-36.2 kW

*Note: Dry sand conditions will require increased tractor power

In complement, the corresponding draft values displayed in Figure 2 (i.e. 13.5-16.8 kN/tyne) can be used to estimate the required weight of the 4WD tractor. Assuming a net traction coefficient of 0.55 in a loose sandy soil (i.e. the tractor may deliver 55% of its weight as drawbar draft – see Zoz and Grisso, 2003), the tractor weight required to sustainably pull this 7 tine implement would be around 17-21 tonnes.

This calculation does not account for tine interactions at conventional tine spacings which would be expected to reduce total draft and tractor power estimates (See Part 2 factsheet). In contrast, the rolling resistance (RR) of depth gauging wheels and rollers, would add extra power requirement (Note: RR is expressed as a proportion of the weight supported by the wheels, and varies strongly with surface conditions, e.g. for 600/55-26.5 tyres in a clay soil context, RR = 6-8% (hard), 13-16% (tilled) and 17-22% (soft), whereby the lowest value in the range applies to radial rather than bias-ply tyre designs – see Kurjenluoma et al., 2009).

Table 1b: Corresponding 4WD tractor engine power (kW net) estimated to pull a 7-tine ripper in moist deep sand at the required depth and speed.**

Depth / Speed	4 km/h	7 km/h
Narrow shank ripper tynes (Image 2)		
400 mm	68-88 kW	145-180 kW
600 mm	161-218 kW	342-428 kW
Delving/mixing ripper tynes (Image 3)		
600 mm	151-202 kW	375-471 kW

**Assumptions: 85% transmission losses, soft soil with 70% tractive efficiency; 90% engine power usage ; no tine interactions, excludes rolling resistance

Impact of tyne design on relative draft

Narrow shank ripping tynes

The selection of 5 narrow shank tynes accounted for a 24% range about the mean draft, on average over the two depths and speeds. The following tine ranking based on draft was relatively stable at these depths and speeds, namely (relative to site average): Tilco tyne at +12%, He-Va tyne at +9%, Williamson-Agri Michel tyne at -1%, Grizzly tyne at -8% and Agrowplow tyne at -12% (see Figure 4). The above average draft requirement for the Tilco and He-Va shanks may be explained by the design solutions featuring narrower point tip and lower lift height, which would create an earlier tendency to operate below critical depth.

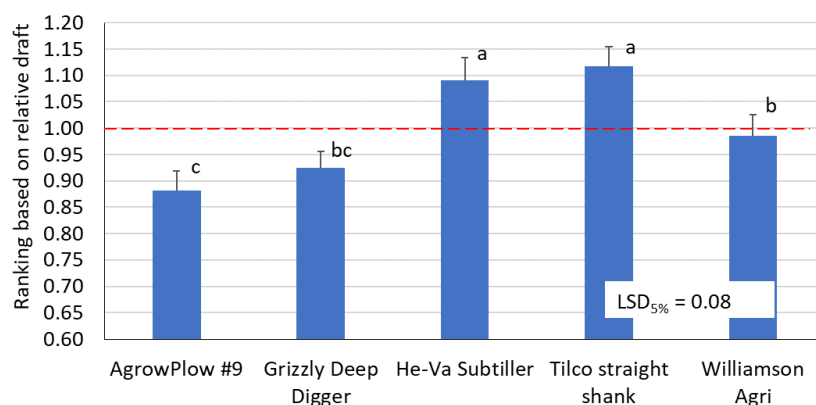


Figure 4: Narrow shank tyne ranking based on draft in moist sandy soil context (4 & 7 km/h and 400-600mm data sets pooled) – 1.0 is the average of the tyne group; Error bars = 1 standard error of the mean (n=16), different letters indicate significant differences at the 5% risk probability level.

Disclaimer: Discrete depth adjustment on the ripper frame allowed each tyne depth to be set only within 2 cm of the target and may have contributed to slight biases between tynes. However, the data suggest optimised tyne design can help minimise ripper draft requirement, but further work is required to validate the ranking of commercial tyne designs under broader soil conditions.

Delving/mixing tynes

The selection of 5 delving/mixing ripper tynes operating at 600 mm depth accounted for a 25% range about the mean draft, on average over the two speeds. The following tyne ranking based on draft was similar at the two speeds (relative to site average), namely: Dondi tyne at +9%, He-Va tyne with face plate at +6%, Lienert delving shank at +4%, Agrowplow #9 delving shank at -3% and Bednar Terraland Active-Mix tyne at -16%. The Bednar Terraland tyne consistently lower draft may be explained by the low angle of approach, lack of mid-level winglets and splitter, compared with those fitted to the higher draft tyne (e.g. Dondi 800 series). The 6% above average draft of the He-Va Subtiller tyne was explained by the steep angle of approach of the bolt-on faceplate.

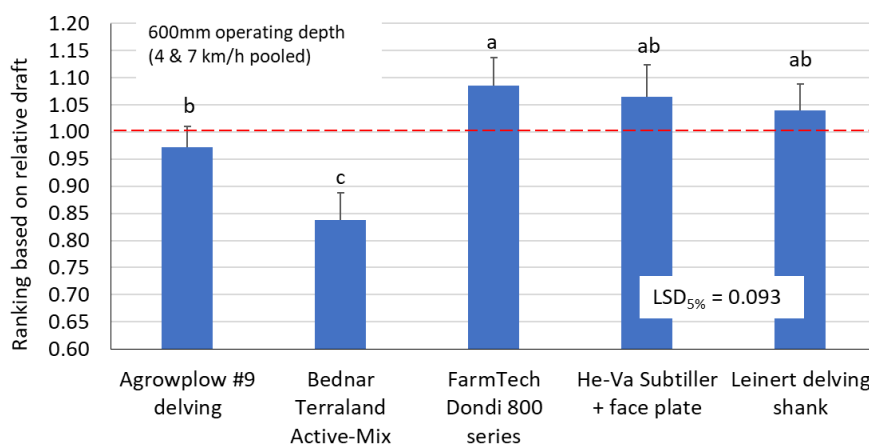


Figure 5: Delving/mixing ripper tyne ranking based on draft in moist sandy soil context (4 vs 7 km/h at 600 mm depth) – 1.0 is the average of tyne group; Error bars = 1 standard error of the mean (n=8), different letters indicate differences are significant at the 5% level.

Disclaimer: Discrete depth adjustment on the ripper frame allowed each tyne depth to be set only within 2 cm of the target and may have contributed to slight biases between tynes. However, the data suggest optimised tyne design can help minimise ripper draft requirement, but further work is required to validate the ranking of commercial tyne designs under broader soil conditions.

Loosening efficiency considerations

Furrow excavations were conducted over the 4 km/h treatments to assess the extent of the furrow cross-sectional area and estimate deep ripping efficiency parameters such as tyne loosening capacity C_T and specific draft D_s .

Tyne loosening capacity (C_T): (See Table 2)

The loosening capacity of narrow shank ripper tynes operating at 4 km/h and 400 mm depth ranged between 74-88% (average 82%) and reduced to a 52-70% range (average 63%) at 600mm, representing a 22.6% reduction and indicating a lesser ability to maintain their loosening capacity when operating deeper, in line with expected critical depth limitations. In an implement layout, optimising the tyne spacing narrower than the depth value would help mitigate against lower tyne loosening capacity and achieve greater loosening in the zone between rip-lines, including via tyne interaction (Note: tyne spacing may become 'too narrow' at the point of increasing the implement draft per metre width).

In contrast, the loosening capacity of delving/mixing tynes operating at 600mm depth fluctuated between 66% and 85% (average 76%), being highest with both the Lienert and Dondi tyne designs, which use wider delving plates. These values highlight a greater ability of delving/mixing tynes to maintain higher loosening when operating deep, in line with the wider blade footprint of these tynes. The narrower spacings often observed on delving/mixing chisel ploughs make these implements high draft but also able to achieve a much fuller loosening at depth.

Table 2: Indicative loosening capacity (100% area = depth x depth as tine spacing) of single ripping tynes operating in moist deep sand (Parrakie SA, 2023).

Operating depth	Narrow shank ripper tynes (Image 2)	Delving/mixing ripper tynes (Image 3)
400 mm	74-88% (av. 82%)	No data
600 mm	52-70% (av. 63%)	66-85% (av. 76%)

Tyne specific draft (D_s): (See Table 3)

The specific draft values of narrow shank tynes ranged between 35-50 kN/m² (average 40.7 kN/m²) when operating at 4 km/h and 400 mm depth. These values increased to 52-60 kN/m² (average 57.7 kN/m²) at the 600 mm depth, representing a 41.6% increase on average and a significant loss in energy efficiency of soil profile loosening. Lower efficiency at deeper depth is a characteristic of narrow shank tynes risking operating below their critical depths and be subjected to high energy subsoil compaction and 'furrow trenching'.

In contrast, the specific draft values of the delving /mixing tynes operating at 4 km/h and 600mm depth ranged between 39-59 kN/m² (average 47.8 kN/m²). The He-Va tyne with bolt-on faceplate achieved a 23% above average specific draft and was the least efficient delving/mixing tine in the set explained by its higher draft (6% above average) combining with its lower loosening capacity (13% below average). The more efficient delving tyne designs were able to achieve similar specific draft values to the narrow shank ripper tynes operating at 400mm depth, explained by their greater loosening capacity.

Table 3: Indicative specific draft* of single ripping tynes operating in moist deep sand (Parrakie SA, 2023).

Operating depth	Narrow shank ripper tynes (Image 2)	Delving/mixing ripper tynes (Image 3)
400 mm	35-50 kN/m ² (av. 40.7 kN/m ²)	No data
600 mm	52-60 kN/m ² (av. 57.7 kN/m ²)	39-59 kN/m ² (av. 47.8 kN/m ²)

*low values indicate higher efficiency of deep ripping

Impacts of adding wings to narrow shank tynes

Image 4 shows the range of narrow shank tynes that were tested with added wings. The wings tested ranged in width (i.e. 200-320mm), lift height (20-95mm) as well as sweep angles (e.g. square vs 30° sweep delta shape wings). While adding wings to a ripper tyne significantly increased its draft force, it also maximised the volume of soil loosened at deeper depth (see Figure 6). In field trials, the loosening capacity of a range of ripper tynes increased from 52-70% (unwinged) to 72-103% (with a range of wings).

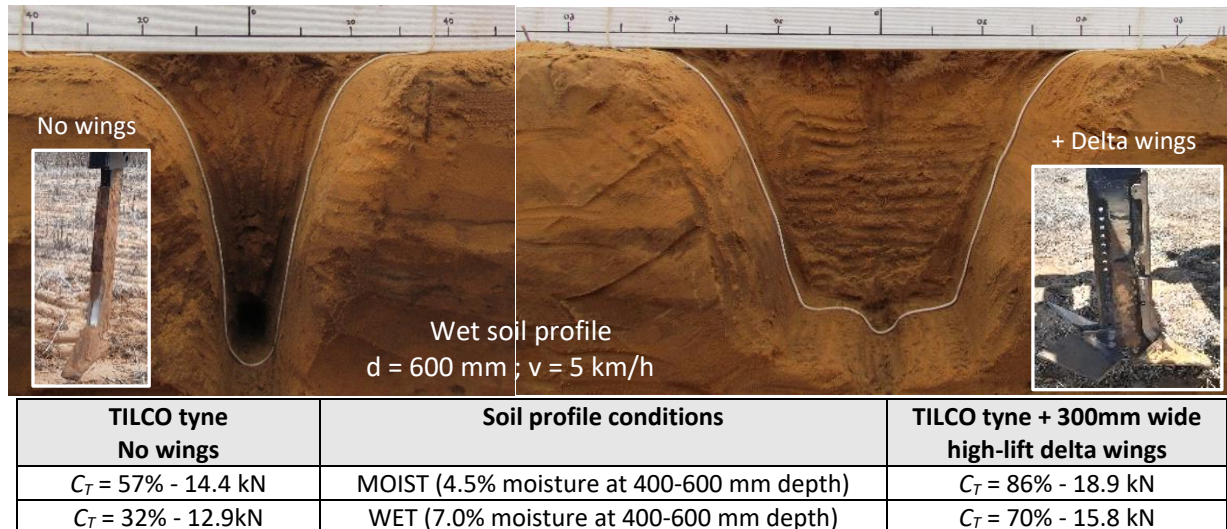


Figure 6: Loosened soil profile visual impact of adding wings to a narrow shank ripper tyne in wet sand conditions (Walpeup Vic, 2023) ; Table values contrast the benefits of adding wings on tyne draft and loosening capacities (C_T) in very wet vs moist ('optimum') soil profile conditions

The specific draft also decreased significantly with winged tynes, as they loosen proportionally more soil volume for the extra draft required. The best outcome was obtained with the Agrisem Cultiplow winged tyne design, reaching 103 % loosening capacity and displaying the lowest specific draft (43 kN/m² at 600 mm operating depth) – see Figure 7.



Image 4: Narrow shank ripper tynes with wings evaluated in Mallee trials (Images: University of South Australia) L to R: Agrowplow #9 shank with 210mm winged blade (35mm lift); Tilco Ag Systems rigid shank with i) 290mm wide Delta wings (20mm lift); ii) with UniSA 310mm wide square wings (40mm lift); iii) with UniSA 310mm wide delta wings (95mm lift); He-Va Subtiller shank with 200 mm wide wings (50mm lift) and Agrisem Cultiplow TC750 shank with 320mm wide wings (80mm lift) and 160mm offset 47mm wide point.

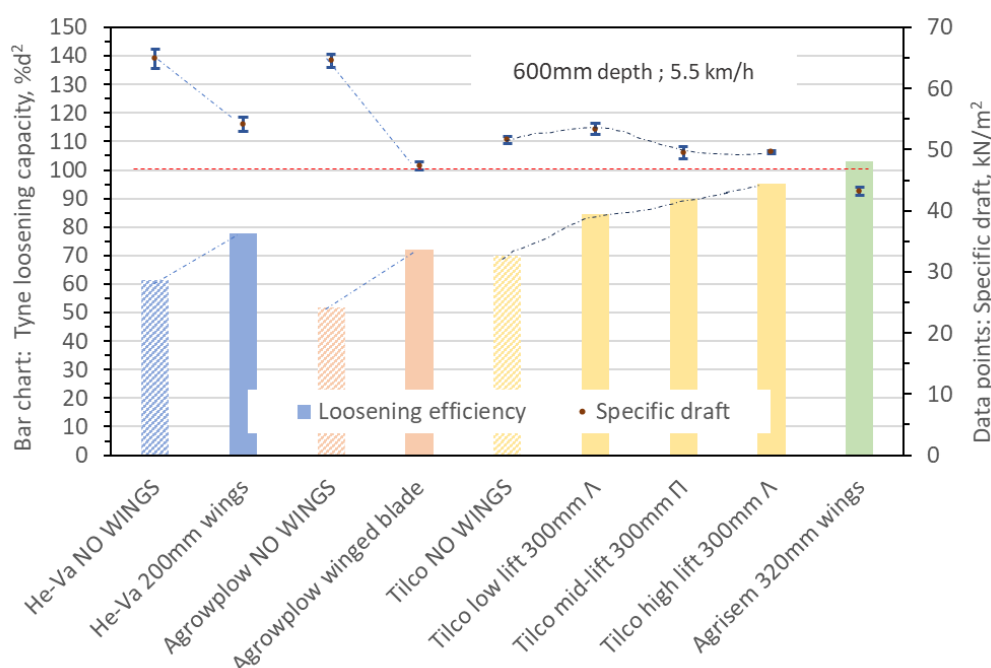


Figure 7: Impact of adding wings to narrow shank tynes on their indicative loosening capacity and specific draft in moist sandy soil conditions (Parrakie SA, 2023) ; Error bars = 1 standard error of the mean (n=8)

Impacts of soil moisture conditions

Deep ripping in dry conditions is known to increase draft, clod size and wear, is significantly more costly and can reduce crop establishment uniformity. Field testing conducted at 600mm depth with a narrow shank tyne in very wet conditions following significant cumulative rainfall (i.e. 7% moisture at 400-600mm depth) highlighted significantly narrower loosened soil profiles relative to 'optimum' moisture conditions (i.e. 4.5% soil moisture at 400-600mm depth) following a significant period of drying.

The tyne loosening capacity reduced from 57% in optimum condition down to 32% in very wet conditions (See Figure 6), while the tyne draft had reduced by 10%, which increased the specific draft by 59% thus showing a sharp drop in efficiency. When using a winged tyne, the loosening capacity reduced from 86% to 72%, respectively (Figure 6), while the draft reduced by 16.4% with little impact on specific draft (+3%). Dry sand soil conditions would lead to significantly greater draft requirements, especially with hardsetting subsoils (such measurements could not be made due to a wet 2023 season).

Conclusions

This factsheet highlights the relative performance of a selection of commercial loosening and delving/mixing tynes available to Australian growers, based upon single tyne field testing conducted in Mallee sandy soils. The findings follow expected trends found in international research, generally conducted in heavier soil types. Overall, the design of deep ripping tynes was found to bear significant impact on tractor power use and efficiency of soil loosening, especially when operating at deeper depth (600 mm). Overall, the 5 tyne selection in each group accounted for a 25% range in draft about the average, but more validation work is required to confirm trends between designs.

Ripping depth was the most important factor in moist deep sandy soil conditions affecting narrow shank ripper tyne draft, measuring a 2.4-fold draft increase from 400 mm to 600 mm depth. Faster operating speed from 4 to 7 km/h increased draft by 15-18% (for narrow shank tynes) and 26-42% (for delving/mixing tynes). Delving/mixing tynes required similar draft to narrow shank ripper tynes at 4

km/h but achieved 19% greater loosening capacity, while required 13% greater draft at 7 km/h explained by the inertia of greater soil movement.

The loosening capacity of narrow shank tynes reduced significantly (-23%) when operating deeper (600 mm vs 400 mm), while their specific draft significantly increased (+42%), both indicating a loss in soil loosening efficiency. The addition of wings greatly improved the tyne loosening capacity and reduced their specific draft. The draft force reduction, and therefore power savings, expected when narrow shank tynes operate in very wet sandy soil conditions are offset by a significant reduction in loosening capacity, which could be offset by the addition of wings. Optimum soil moisture conditions for deep ripping need to avoid both dry (hardset) and excessively wet conditions to optimise efficiency and reduce the cost of ripping.

The above data clarify avenues for optimising power requirement by careful setting of deep ripper depth, optimising the timing of ripping regarding soil moisture conditions, reducing operating speed and selecting lower draft tyne designs (subject to confirmation of trends). These data sets can also be used to estimate tractor power requirements. A separate Part 2 factsheet will address the impact of tyne spacing and layout configuration on deep ripper power requirement and loosening efficiency.

USEFUL RESOURCES

GRDC Factsheet: Ripping Technology (2022). *Technology considerations for cost-effective subsoil loosening*. www.grdc.com.au/resources-and-publications/all-publications/factsheets/2022/ripping-technology-national-factsheet

Weill A. (2015). A Guide to Successful Subsoiling. https://cetab.bio/wp-content/uploads/2015/11/weill_2015_guide_to_successful_subsoiling_cetab.pdf

REFERENCES

ASABE Standards. (2015). ASAE D497.7 MAR2011 (R2015): Agricultural Machinery Management Data. St. Joseph, MI: American Society of Agricultural and Biological Engineers.

Zoz FM and Grisso RD (2003). Traction and Tractor performance. ASAE Distinguished Lecture # 27. <https://elibrary.asabe.org/data/pdf/6/ttp2003/Lecture27.pdf>

Kurjenluoma et al. (2009). Rolling resistance and rut formation by implement tyres on tilled clay soil. *Journal of Terramechanics*. 46(6): 267-275.

MORE INFORMATION

Jack Desbiolles, University of South Australia (AMRDC)
jacky.desbiolles@unisa.edu.au ; M: 0419 752 295

Chris Saunders, University of South Australia (AMRDC)
chris.saunders@unisa.edu.au ; M: 0419 752 292

GRDC Code: MSF2201-001SAX

DISCLAIMER Any recommendations, suggestions or opinions contained in this publication do not necessarily represent the policy or views of the Grains Research and Development Corporation. No person should act on the basis of the contents of this publication without first obtaining specific, independent, professional advice. The Corporation and contributors to this Fact Sheet may identify products by proprietary or trade names to help readers identify particular types of products. We do not endorse or recommend the products of any manufacturer referred to. Other products may perform as well as or better than those specifically referred to. GRDC will not be liable for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information in this publication.

CAUTION: RESEARCH ON UNREGISTERED AGRICULTURAL CHEMICAL USE Any research with unregistered agricultural chemicals or of unregistered products reported in this document does not constitute a recommendation for that particular use by the authors or the authors' organisations. All agricultural chemical applications must accord with the currently registered label for that particular agricultural chemical, crop, pest and region.

Copyright © All material published in this Fact Sheet is copyright protected and may not be reproduced in any form without written permission from GRDC.