SOIL INVERSION BY PLOUGHING

FACT SHEET

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

SOUTHERN AND WESTERN

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Technology considerations for inversion ploughing of sandy soils

Photo: Evan Collis

Mouldboard ploughing and seeding at Mullewa, WA.

KEY POINTS

- **Mouldboard, disc or square ploughs can address surface soil constraints by inversion and burial but their performance can be affected by a range of factors**
- **A key function of ploughing in sandy soils is to invert the 0 to 400mm soil profile and bury surface-applied amendments, stubble residue, non-wetting topsoil and resistant weed seeds**
- **Ploughs with skimmers (set correctly) will more successfully invert and reliably bury the surface layer to depth**
- **The speed of work has significant effects on the quality of burial, with each plough performing best at an optimum speed. Generally, a speed above 7.5km/h leads to performance decreases**
- **One-way disc ploughs are not as effective at burial as mouldboard ploughs, especially at higher forward speeds, and work better in deep sands where penetration is stable**
- **Better results are achieved when ploughing is carried out at the correct soil moisture, waiting until later in the season when moisture increases generally improve performance**
- **Post-ploughing management is critical to optimise crop establishment and minimise erosion risks**

INTRODUCTION

This fact sheet summarises the latest on the mechanics of inversion ploughing following recent research in Western and Southern Australia. Discrete Element Method (DEM) computer simulation has been used to investigate the effect of operating parameters for a range of ploughs with a focus on surface layer burial performance, particularly in sandy soil environments across the two regions. These computer simulations were field-validated for both mouldboard and disc ploughs in WA and SA.

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Figure 1a: Kverneland mouldboard body and skimmer.

Source: UniSA

Figure 1b: Gregoire Besson mouldboard plough with hydraulic auto-reset.

Source: UniSA

Figure 2a: John Shearer prototype two-way high work rate disc plough with concave disc skimmers.

Source: UniSA

Figure 2b: Plozza-modified John Shearer 5GP one-way disc plough.

Source: UniSA

Figures 3a (top) and 3b (bottom): TATU reversible square plough.

Source: Serafin Machinery website

The major challenge for inversion technology is to achieve a complete and reliable inversion when surface layers are soft, very dry and free flowing.

PLOUGH TECHNOLOGY

Inversion ploughs can be found in three main forms, all of which are available in Australia.

Mouldboard ploughs (MB) come in a vast array of sizes; they can be three-point linkage (3PL) mounted, semi-mounted or trailed, offering three to 19 furrow bodies and consist of a central frame that runs the length of the machine to hold the soil-engaging parts in place. Mouldboard ploughs can be one-way or turnover (reversible). Mouldboard ploughs contain a large number of soil-engaging parts and therefore are seen as complicated and expensive, especially when fitted with auto-reset protection (Figure 1b). The mouldboard component has a complex curved surface that is intended to lift, carry and turn soil completely over into the adjacent open furrow. This 100 per cent inversion is helped by the addition of a skimmer, which is a small mouldboard-shaped tool leading the main body and ensuring the corner of the inverted slice is first cut-out and buried, before the main slice inversion. Side forces are dealt with via the landslide, engaging with the furrow wall and keeping the plough travelling straight.

Disc ploughs (DP) also come in a range of sizes but are far simpler, with only a freely rotating disc engaging with the soil at each furrow. Disc ploughs have historically only supported a one-way ploughing operation, with only a few smaller 3PL-mounted models being used in a swing configuration to allow two-way ploughing operation. Accessories can be fitted to aid soil inversion but often with limited impact on residue burial. Trailed one-way disc ploughs were widely used in Australia before the advent of no-tillage farming in the 1980s for weed control and seedbed preparation following traditional fallows. With relatively small disc diameters, these ploughs were limited in working depth. More recently, these one-way trailed disc ploughs have had a resurgence by being modified to having fewer but larger discs, enabling them to work deeper and invert more soil for deeper soil profile amelioration. This development was driven by the Plozza brothers in WA (Figure 2b). One key operational aspect of the disc plough is the requirement to provide side force stability independently of each plough disc, which can be problematic. Recent progress has seen the development of a two-way high work rate disc plough (Figure 2a) with dedicated skimmers to achieve 100 per cent inversion at high speeds, which has not previously been available with disc ploughs.

Square ploughs (SP) are the least common plough found in Australia but have started to gain some momentum due to their relative simplicity, similar to the disc plough, and perceived robustness. They use simple symmetrical furrow boards engaging with the soil in two directions via a hydraulically operated swing beam, which allows for two-way ploughing operations (Figures 3a and b). These imported ploughs are cheaper than mouldboard ploughs, which gives them appeal and a place in the market. The steep symmetrical furrow board is also a compromise in shape and inversion ability. Square ploughs are also able to rely on a landslide component to stabilise the side forces, but do not incorporate skimmers to improve the burial efficacy of topsoil.

INVERSION PLOUGHING PRINCIPLES

Modern ploughs have had incremental changes in their design over time, but the principles remain the same: cutting a soil slice to the working depth required, turning the whole furrow slice over and placing it into the adjacent open furrow. This needs to be done as efficiently as possible with the aim to bury 100 per cent of the old surface soil, leaving sublayer soil on the surface.

This is often not easily achieved in dry sandy soils, where free flowing soft soil does not invert easily. This can improve as sandy soil moisture increases and develops cohesive strength. GRDC-funded research has investigated, through field-testing and DEM computer simulation, some of the factors that affect the burial efficacy of surface layers with a range of mouldboard and disc ploughs.

EVALUATING PLOUGH PERFORMANCE VIA DEM ANALYSIS

When assessing the performance of a plough, the following are key considerations:

- burial – quantity buried vs left on the surface, distribution depth of burial within the ploughed profile; and
- plough design and settings – type of plough, speed of operation and field settings (skimmers, disc rake and sweep angles).

A full-scale mouldboard plough operating in computer simulation space was used to visualise and evaluate the ability to bury the surface layer (Figures 4a and b). A blue layer of particles was put onto the surface and used as a method of quantification to assess the inversion performance.

As can be seen in Figures 4a and b, the blue particles originally on the surface are buried as the plough passes over them, leaving minimal blue particles visible on the surface, with the majority found in pockets below the surface along each furrow.

The DEM simulations were then used to investigate the impact of speed on surface burial efficacy of a range of mouldboard and disc ploughs.

Figure 4a: Side view of computer-simulated mouldboard ploughing, crossing a band of blue surface particles.

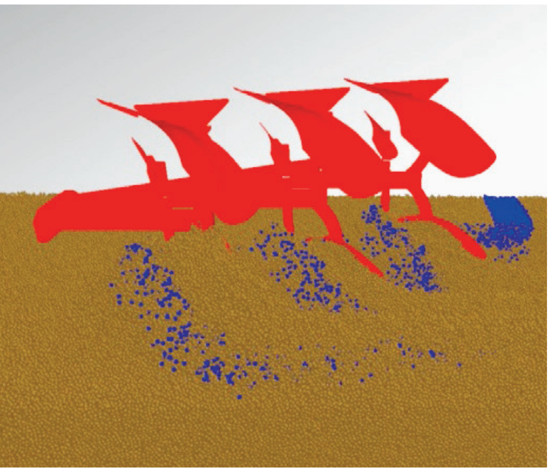
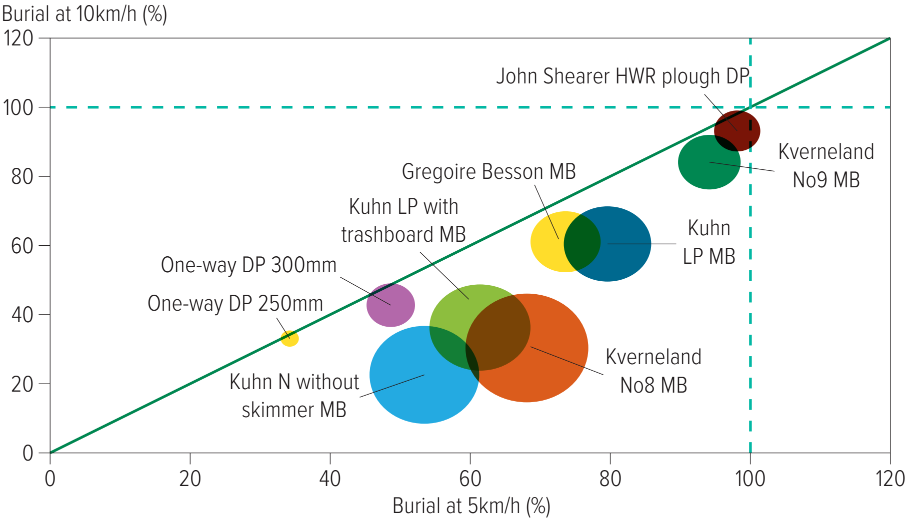


Figure 4b: Rear view of simulated ploughing showing the burial pattern of blue surface particles.

Source: UniSA

Figure 5: Comparison of surface layer burial efficacy for a range of plough types and bodies at two speeds.

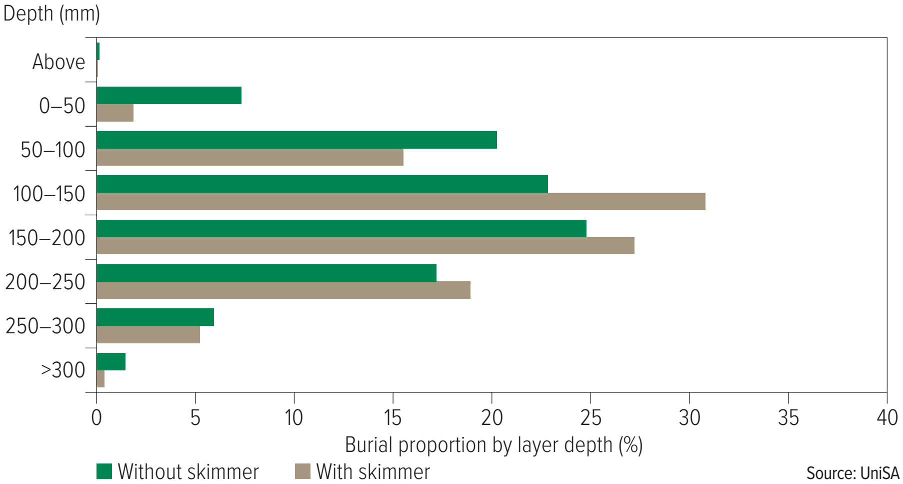


— 1:1 line DP = Disc plough HWR = High work rate LP = Multipurpose cylindrical body
N = Multipurpose helical body MB = Mouldboard

Larger circles denote a greater range of soil burial outcomes. Circles below the 1:1 line illustrate the reduction of relative burial efficacy at higher speed.

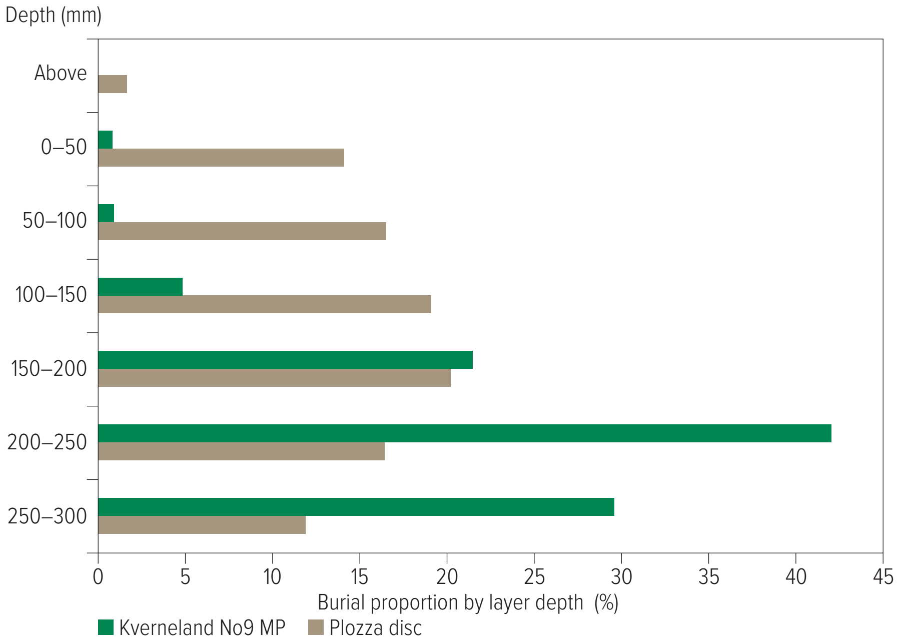
Source: UniSA

Figure 6: Increase in surface sandy topsoil burial from the addition of skimmers.



Source: UniSA

Figure 7: A comparison of surface layer burial by a mouldboard plough and a one-way Plozza disc plough at 5km/h.



Source: UniSA

Figure 8a: Effective burial by mouldboard plough fitted with skimmers, showing concentration of surface residue at the bottom of furrow (highlighted with pH indicator).

Source: Stephen Davies

Figure 8b: Incomplete topsoil burial with mouldboard plough at Geraldton, WA.

Source: UniSA

Figure 5 shows the different burial percentages of a range of plough types and mouldboard bodies at two speeds.

For example, the Kuhn LP MB buried 80 per cent of the surface layer at five kilometres per hour (horizontal axis) but when the speed was increased to 10km/h (vertical axis), the mouldboard only achieved 60 per cent burial (vertical axis). Overall, across the range of ploughs investigated, the lower end of burial efficacy measured as 45 per cent at 5km/h, reduced down to 10 per cent at 10km/h.

DEM computer simulation was used to investigate the benefit of skimmers fitted on mouldboard ploughs. Skimmers improve the ability to complete the full burial of surface material as shown in Figure 6. While skimmers are commonly set to about 50mm depth below the soil surface, a deeper depth may be needed if aiming to bury a thicker surface (for example, a water-repellent layer).

For considering the type of plough to choose, DEM was used to investigate the surface layer burial performance of a mouldboard versus a disc plough. Simulation results indicate that using a mouldboard plough provides significantly better topsoil burial, and the improvement over a one-way disc plough is more prominent as speed increases. For instance, Figure 7 shows that the mouldboard plough operating at 300mm depth removed most of the surface soil from the 0 to 100mm layers and significantly increased the burial in the 200 to 300mm depth when compared with the disc plough.

PADDOCK EVIDENCE

When a mouldboard plough is set up correctly, 100 per cent topsoil burial should be achievable and sufficiently deep in to the profile. Figure 8a shows how the crop residue has been inverted to a position at the bottom of the ploughed profile, with the pale subsurface sand covering the darker surface-layer soil. Figure 8b shows that if the plough is set up and used incorrectly, surface material can be left on the surface, often visible as narrow bands at the interface of each furrow. These surface bands often carry a legacy of old surface layer issues such as weed seed germination and water repellence. Suboptimal burial typically occurs without skimmers or if the skimmer depth or lateral positions are not set correctly in relation to the main mouldboard body. Figures 9a and b show cross sections of ploughed profiles with a blue/green surface tracer that was used to evaluate performance. There is generally a wider spread of surface material through the profile with a typical J-shape curve running from down in the profile up to the surface between each ploughed slice. Slower speeds should be used to obtain good burial while ploughing in greater soil moisture can also improve burial performance in sand.

One-way disc ploughs often do not work well in harder soils where the stability of soil penetration can be an issue or when the operational speed is too high, leading to very poor burial performance. Figure 9b shows where the blue/green tracer and crop residue can be seen on the surface and very shallow in the profile. The discs were working too shallow to be filled with sufficient soil to enable effective inversion.

POST-PLOUGHING MANAGEMENT

Regardless of which inversion plough type is used, the post-ploughing conditions result in a very soft seedbed and a residue-free surface that is very prone to wind erosion. This represents a major challenge for quickly re-establishing ground cover including the follow-up grain crop establishment.

A key first step involves a rolling operation to consolidate the soft soil and facilitate the seeder pass by minimising sinkage, deep rutting legacy and uncontrolled depth of seed placement.

Figure 9a: Good performance with a one-way Plozza disc ploughing at Malinong, SA. Red circling shows blue-coloured surface tracer effectively buried deep.

Source: UniSA

Figure 9b: Poor performance with a one-way Plozza disc ploughing at Bute, SA. Red circling highlights evidence of blue-coloured surface tracer remaining visible on the surface.

Source: UniSA

The rolling operation can be problematic if the weight and size of the tractor and roller are not matched properly (Figure 10).

As part of an improved disc plough development carried out by the University of South Australia (UniSA) and John Shearer under GRDC investment, a one-pass ploughing and seeding solution was developed and tested. This used a proof-of-concept high floatation seeder, which can be towed with the plough or used separately after ploughing.

It features seeding coulters designed for clean and tilled seedbeds (Figure 11) to improve seed placement depth control and large floatation wheels to consolidate the seedbed with minimal sinkage, leaving ridges for wind erosion protection.

A towed seeder concept had been tried by WA grower Mick Fels by adapting an old combine seeder towed behind a square plough.

If seeding behind the plough is not practical, increasing the seeding rate, adopting a two-pass cross-seeding or combining seed broadcasting followed by the tyne seeder are strategies used. Some growers have built light seeder bars with simple shallow seeding boots and press wheels to better accommodate

Figure 10: Post-ploughing rolling operations at Cowangie, Victoria, challenged by sinkage and traction limitations due to soft seedbed

Source: UniSA

soft soil conditions. As seen in the top half of Figure 12, combined seeder and seed broadcasting were used to achieve greater plant numbers and ground cover is a recommended approach to effectively stabilise the loose soil and resist the impact of high winds.

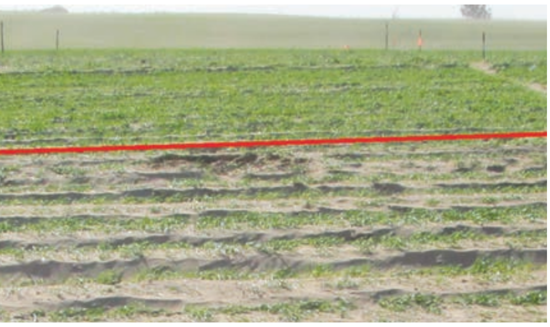
Another important consideration is the redistribution and/or dilution of organic carbon (OC) and nutrients following inversion/burial. Research has shown that OC and nutrients are buried deeper in the soil profile (20 to 30 centimetres), so while they are not lost from the system, the amount in surface layers may not meet the nutritional needs of emerging crops, calling for appropriate agronomic management.

POST-PLOUGHING AGRONOMIC MANAGEMENT

- Supply extra nitrogen and sulfur early in the growing season to boost early biomass production and encourage tillering.
- Conduct a strategic soil sampling program in the second year after amelioration (once the site has settled) to assess nutritional status in the top 100mm. Sampling care is needed to control soil nutrition variability on the edge of plough furrows in contexts where burial is poorly achieved and should include a greater number of samples.
- Supply a customised nutritional package to boost soil fertility and meet the new crop's demand.
- Take care with choice of pre-emergent herbicide products and rates as soil-applied herbicide activity and risk of crop damage can be enhanced following inversion tillage. Use products known to be 'safe', consider using rates at the lower end of those recommended on the label, and consider post-sowing pre-emergent and post-emergent options to safely ensure control of surviving weeds.

Figure 11: John Shearer high work rate prototype full inversion disc plough and one-pass seeder.

Figure 12: A visual comparison of conventional seeding (in foreground) versus zero row spacing (seeder plus additional broadcast in background) to improve post-ploughing crop establishment and resistance to high winds.



USEFUL RESOURCES

GRDC *GroundCover* (2019): 'Effective set-up' groundcover.grdc.com.au/agronomy/soil-and-nutrition/effective-set-up

GRDC *GroundCover* (2019): 'A tale of two ploughs' groundcover.grdc.com.au/agronomy/soil-and-nutrition/a-tale-of-two-ploughs

GRDC *GroundCover* (2021): 'Tips for using a modified one-way plough for soil mixing and inversion' groundcover.grdc.com.au/innovation/precision-agriculture-and-machinery/tips-for-using-a-modified-one-way-plough-for-soil-mixing-and-inversion

DPIRD *Agriculture and Food:* 'Soil inversion to ameliorate soil water repellence' agric.wa.gov.au/water-repellence/soil-inversion-ameliorate-soil-water-repellence

GRDC Update Paper (2023): *Strategic tillage: how does it impact weed management?* grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2023/02/s8-borger-catherine

Kverneland Group UK Ltd, *Ploughing Guide* uk.kvernelandgroup.com/content/download/96770/868716/version/2/file/Ploughing+Guide+-+Single+Pages+2008.pdf

MORE INFORMATION

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