IMPROVING THE EFFECTIVENESS OF SOIL AMELIORATION BY OPTIMISING SOIL MACHINE INTERACTION

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AUTHORS

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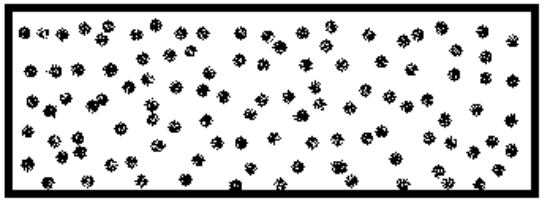
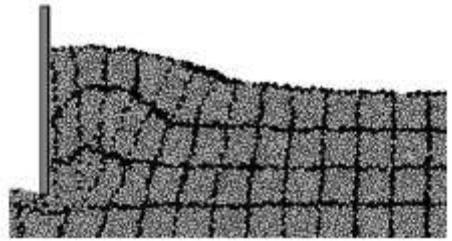
DIFFERENCES BETWEEN SOIL AND OTHER GRANULAR MATERIALS

- Modelling of soil-tool interaction is a complex process due to the variability of the soil profile, non-linear behaviour of the soil material, and the dynamic effect of the soil flow.
- There is no exact particle shape
- Particle sizes are too small so using of real particle sizes significantly increases the computation time.

- **DEM can overcome the limitations of analytical, empirical and continuum numerical models which can only be used to model the tillage forces but not the soil movement or subsequent profile**





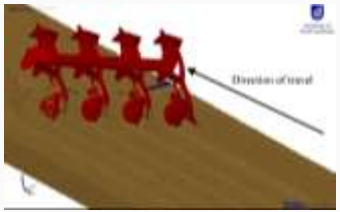
CALIBRATION OF DEM PARAMETERS

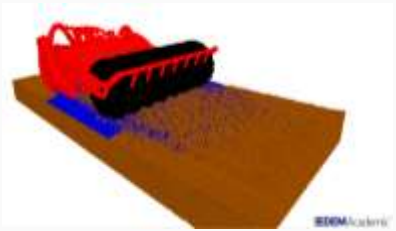
- When bulk granular materials are poured onto a horizontal surface, a conical pile will form. The internal angle between the surface of the pile and the horizontal surface is known as the angle of repose (Yadav and Yadav, 2009).

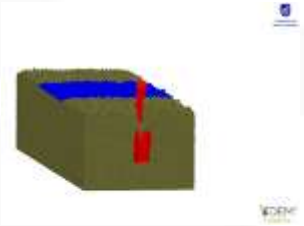
A new system was designed and made at UniSA to standardize the method.

METHODOLOGY

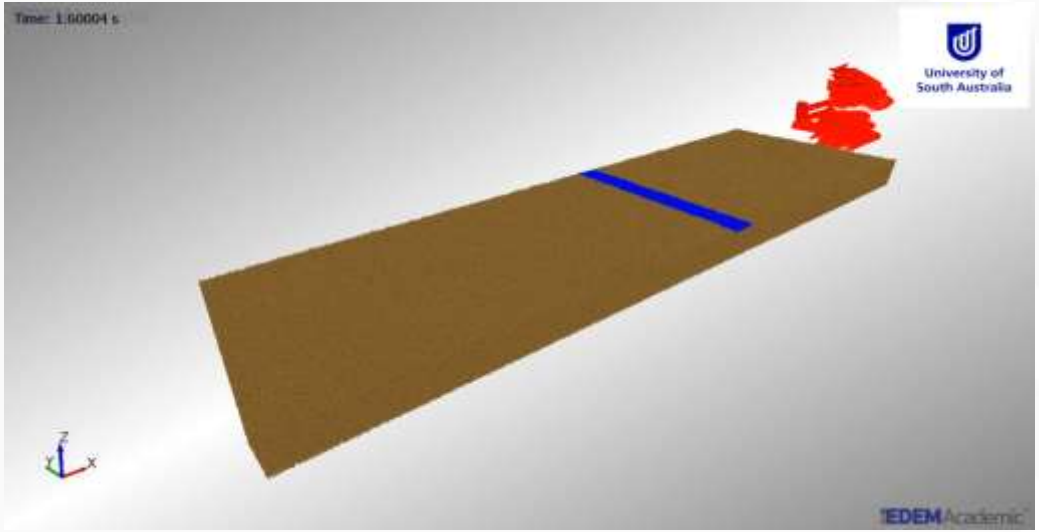
- The movement of the topsoil by ploughing, mixing and topsoil inclusion was measured by tracking the soil movement during the tillage operation.
- To achieve this, a shallow recess was dug across the path of the tool and filled with blue coloured sand. After the tillage operation, face pits were excavated across the direction of travel and a digital photo of each vertical slice was taken (Scanlan and Davies, 2019).

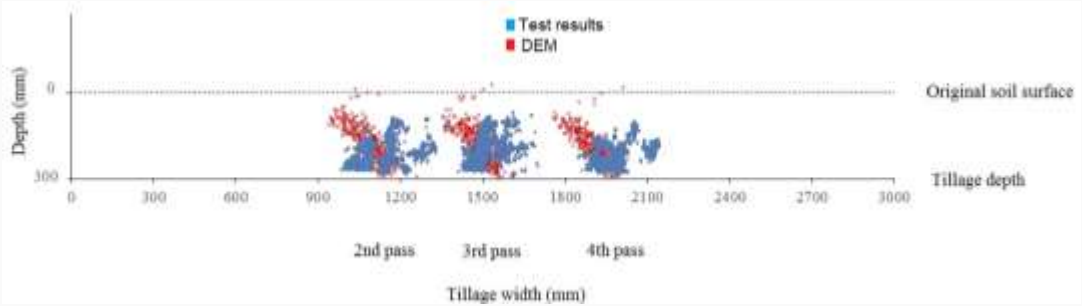




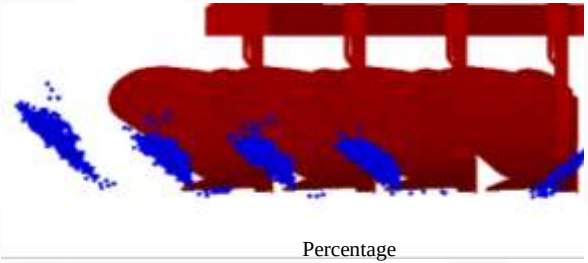


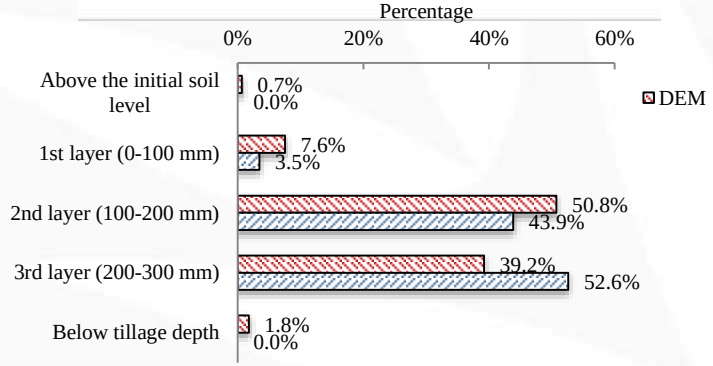
RESULTS



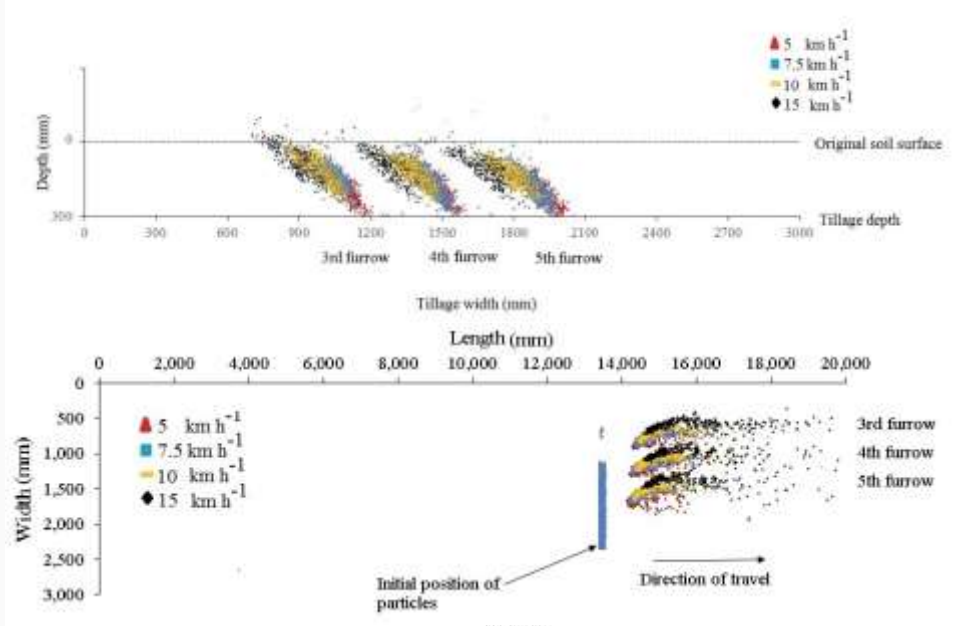


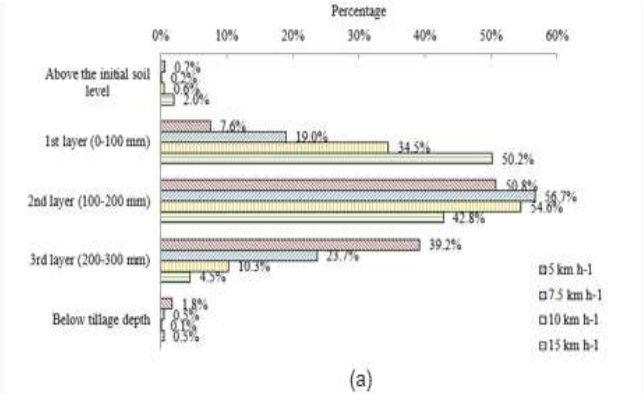
Measured and simulated topsoil burial example results





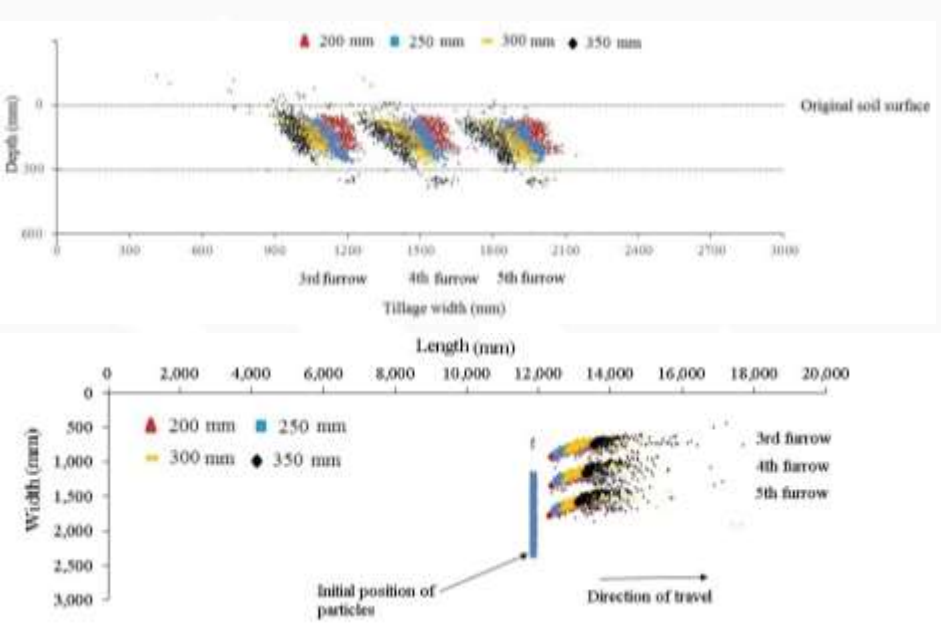
Quantified data: percentage of 40mm topsoil by depth

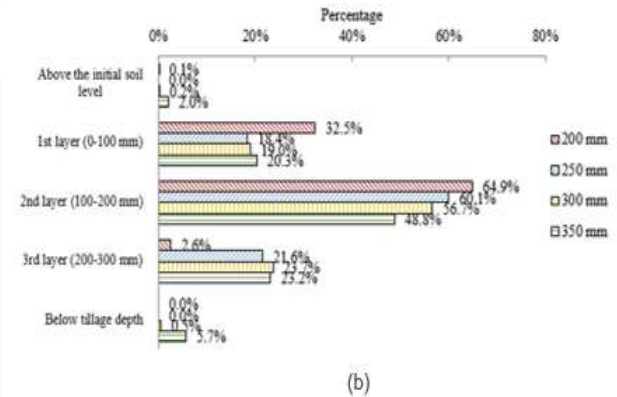




(a)

Effect of speed

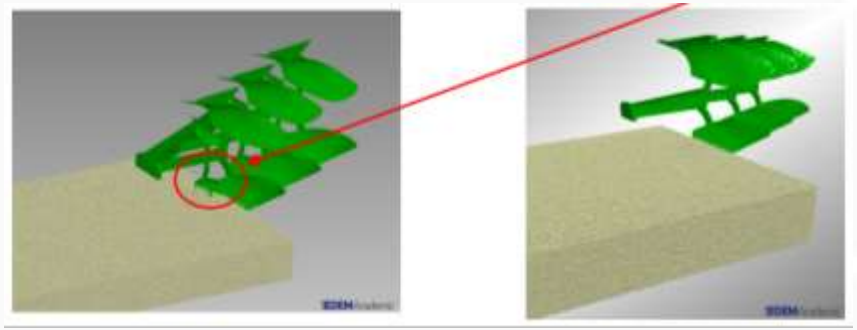


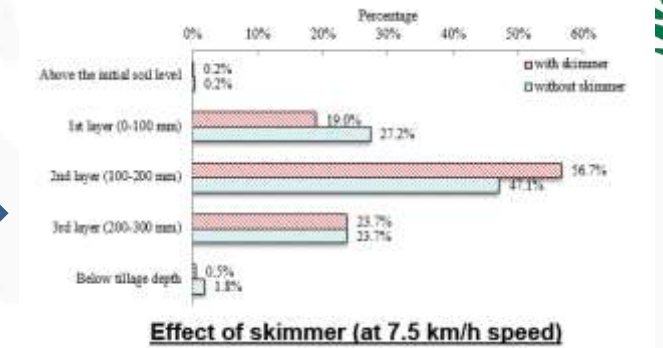


(b)

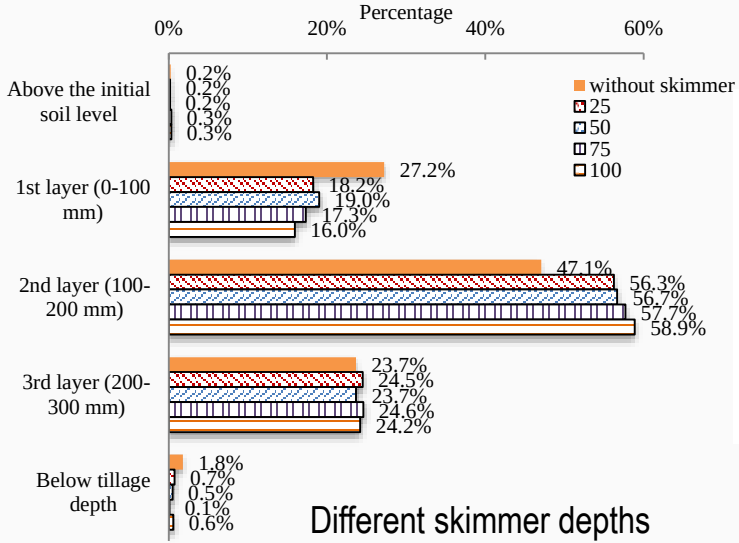
Effect of depth

Accounting for ploughing configuration: Skimmer

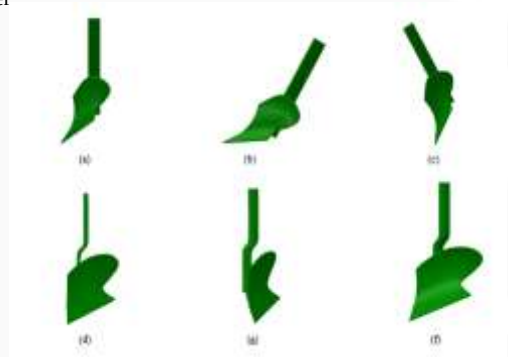




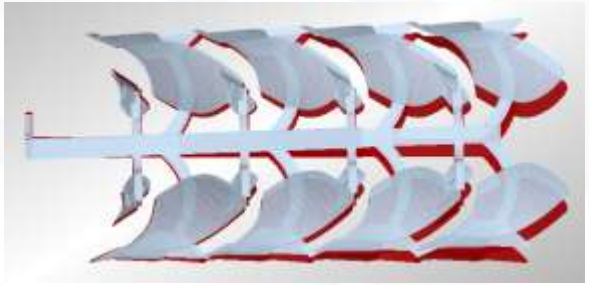
Effect of skimmer (at 7.5 km/h speed)



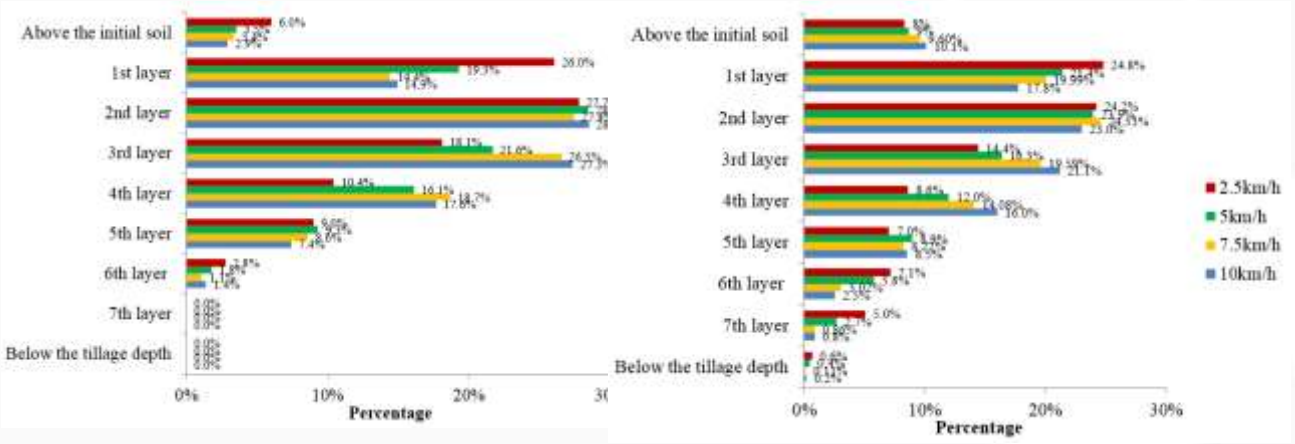
Different skimmer depths

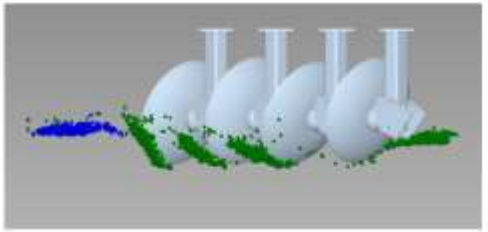


Different skimmer configurations



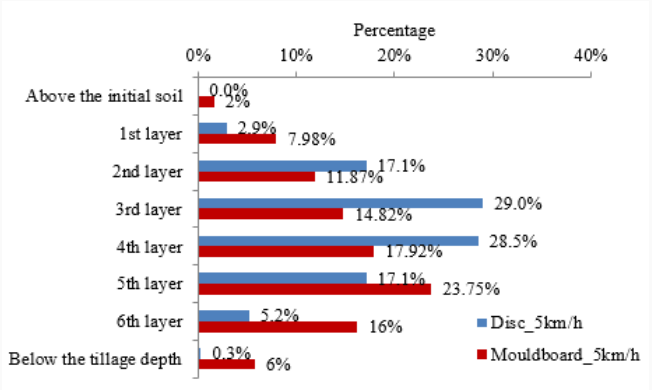
Wrong set-up

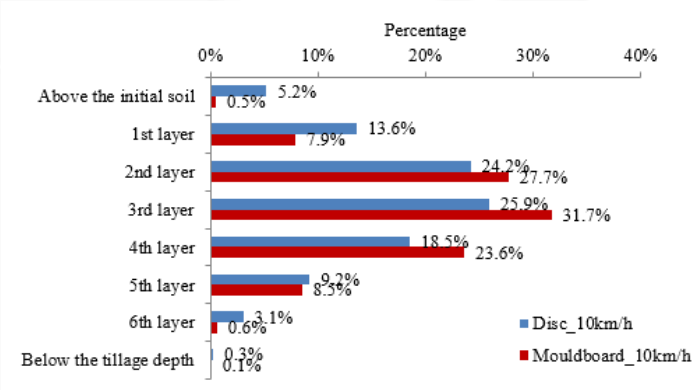




more complex modelling is required

Comparison of percentage of topsoil burial in each depth 50 mm layer for disc plough for 2.5, 5, 7.5 and 10km/h forward speeds at (a) 250mm and (b) 350 mm tillage depths





Comparison of percentage proportions top soil layer buried in each 50 mm thick depth layer for disc and mouldboard ploughs operating at 300mm depth and contrasting (a) slow (5km/h) and (b) fast (10km/h) forward speeds

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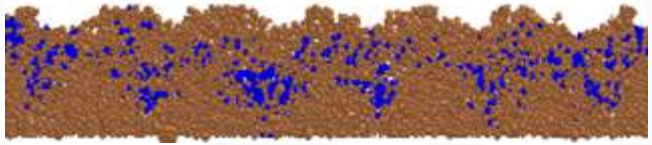
DEM

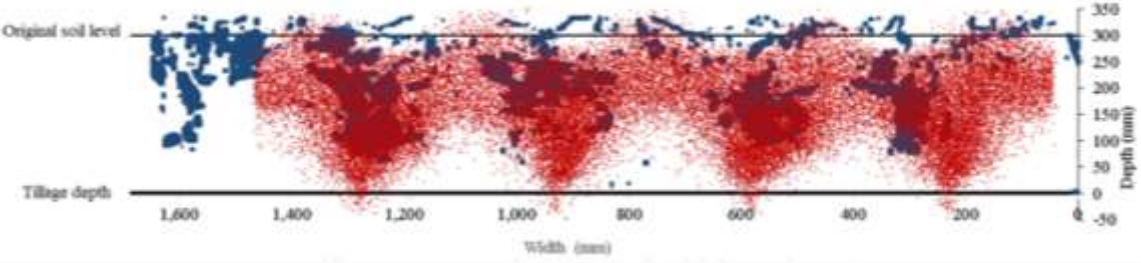
250 mm- 2.5 km/h

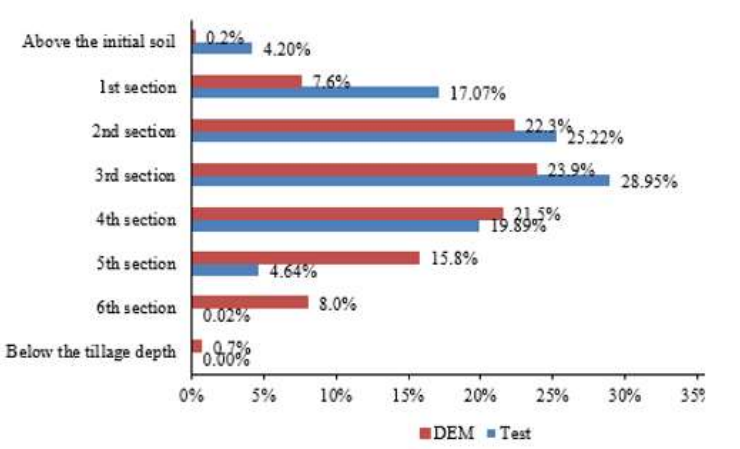
250 mm- 5 km/h

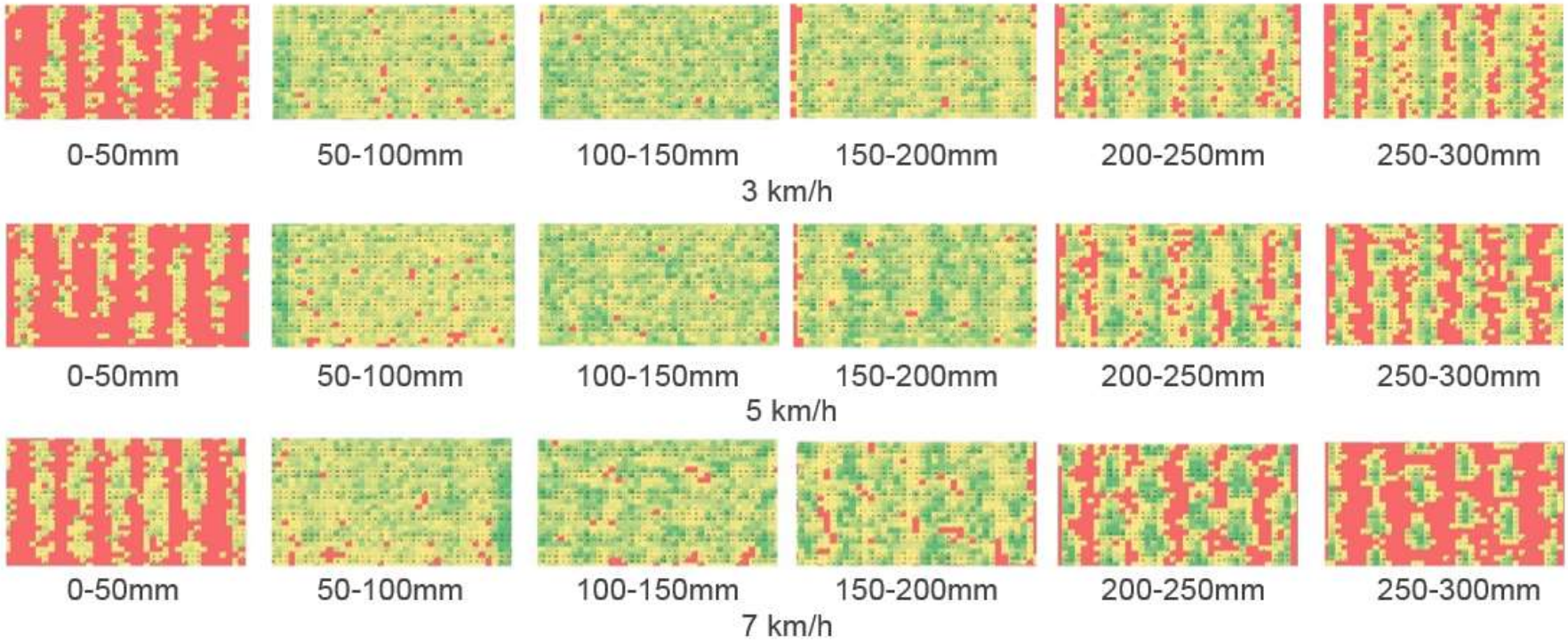
Longitudinal view

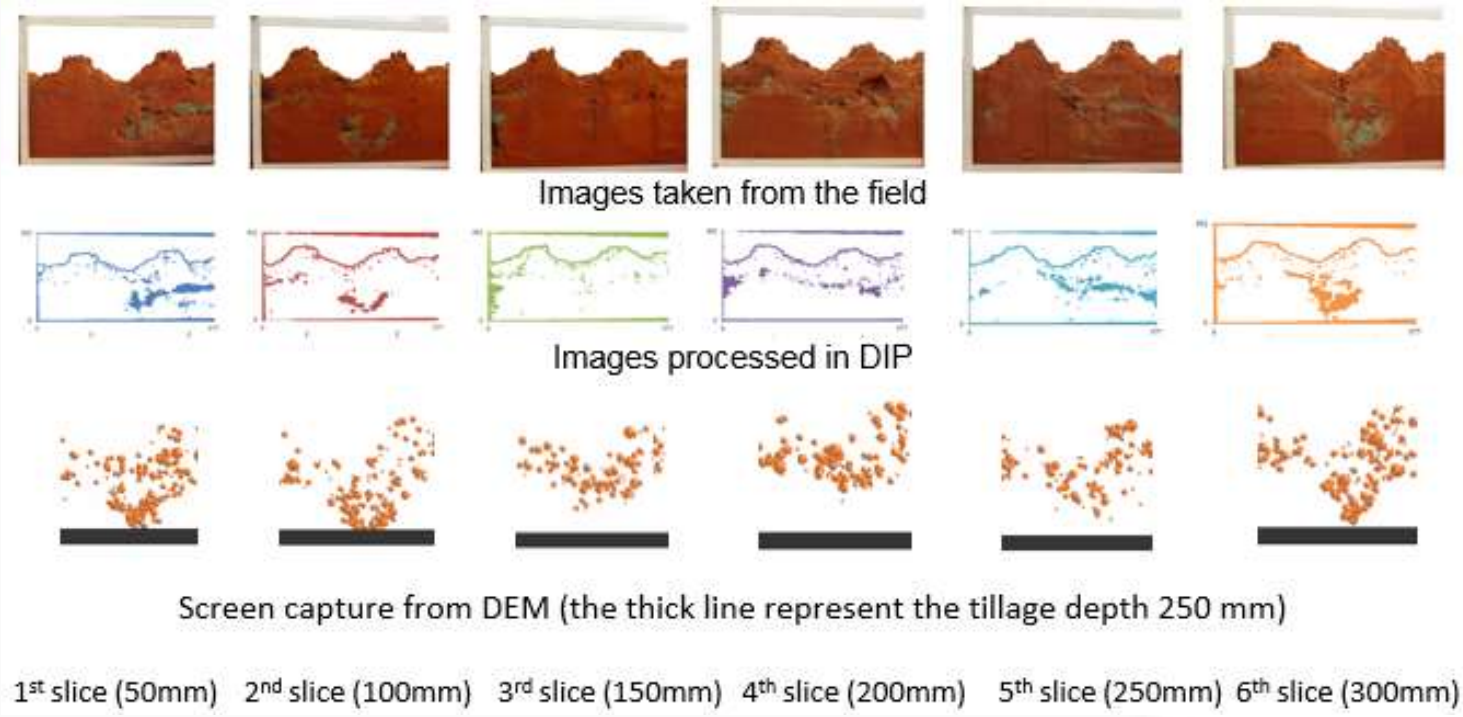


Cross sectional view



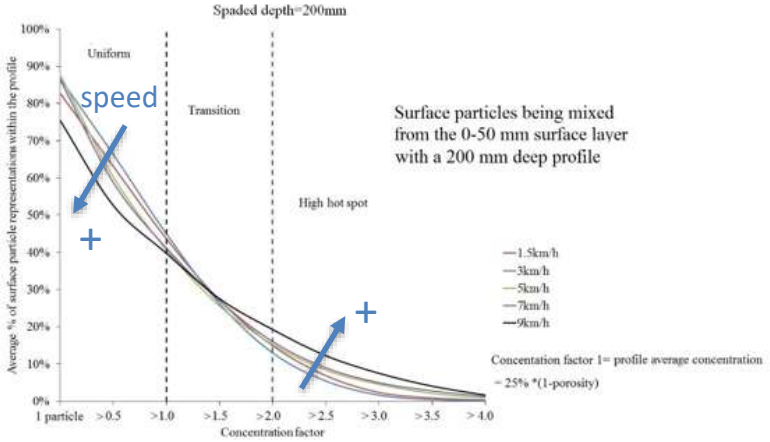



0-50mm
50-100mm
100-150mm
150-200mm
200-250mm
250-300mm
3 km/h
0-50mm
50-100mm
100-150mm
150-200mm
200-250mm
250-300mm
5 km/h
0-50mm
50-100mm
100-150mm
150-200mm
200-250mm
250-300mm
7 km/h

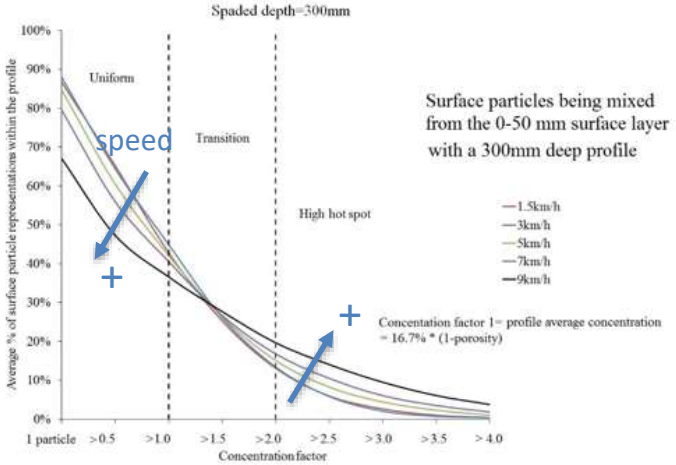


Higher uniformity of mixing in sandy soils is likely to be an advantage for incorporating products like clay and lime, which purportedly need a thorough blending to best achieve their aims. It may be that a best response can be secured by low speed and reverse direction multi-pass spading to maximise the uniformity aspects. However, it is also possible that 'distributed hot spots' - rather than uniform blending at depth of surface manures and organic matter amendments could be beneficial for crops.

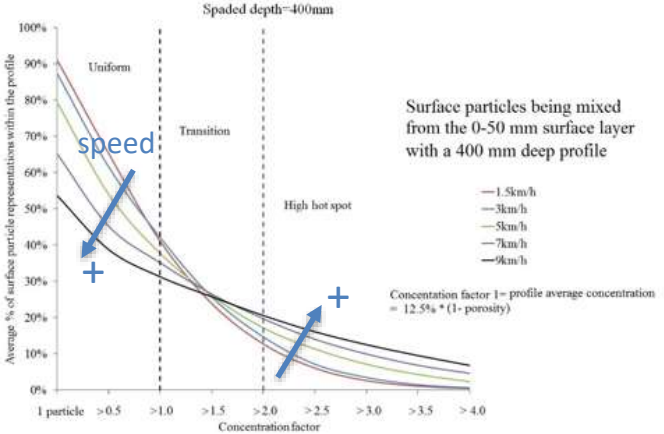
Impact of speed on the proportion of the spaded soil profile affected by concentration of surface layer soil particles



Impact of speed on the propotion of the spaded soil profile affected by concentration of surface layer soil particles



Impact of speed on the proportion of the spaded soil profile affected by concentration of surface layer soil particles



Spading in dry sandy soil vs sticky wet soil

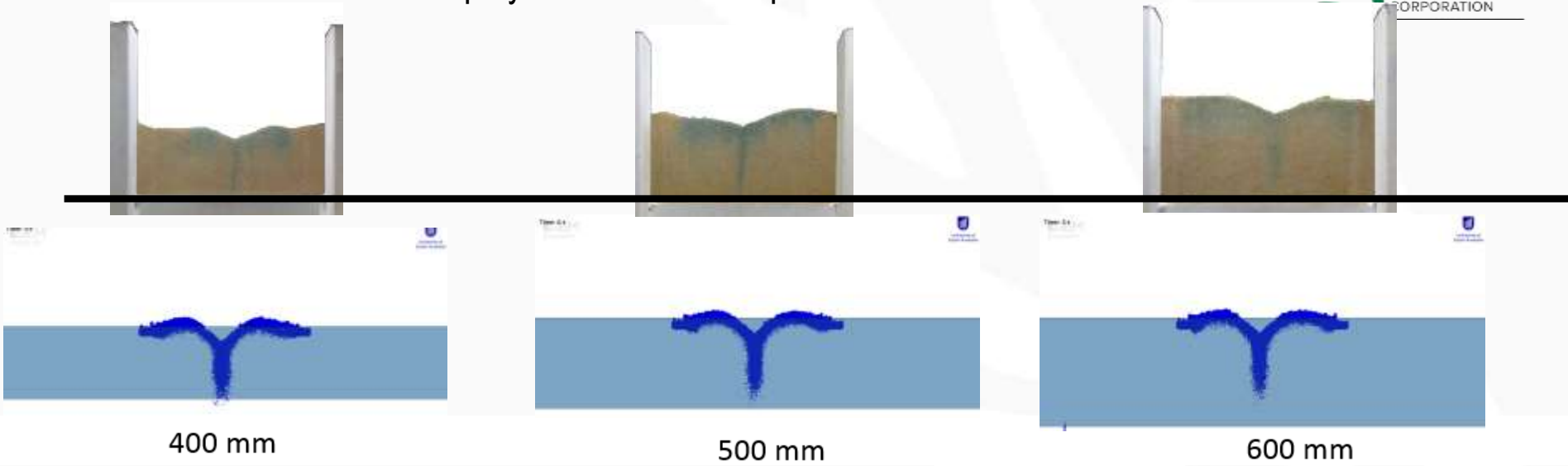
Draft force 2.5 kN

Dry sandy soil

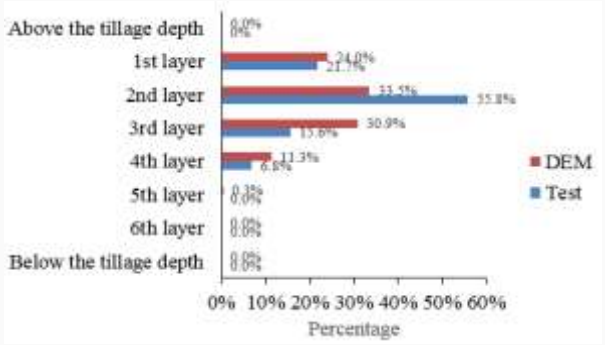
Draft force 3.5 kN

Sticky wet soil

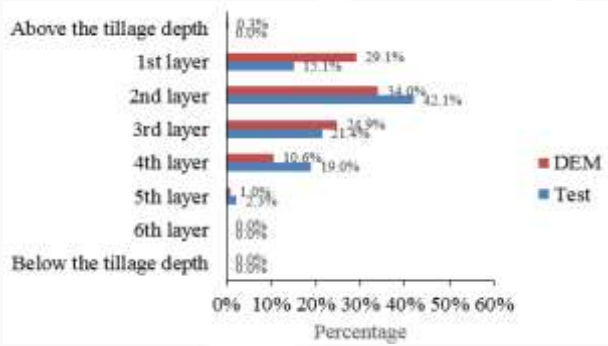
Ripper and inclusion plate results based on soil bin testing and DEM simulations carried out at 1/5 scale and displayed at full scale equivalent



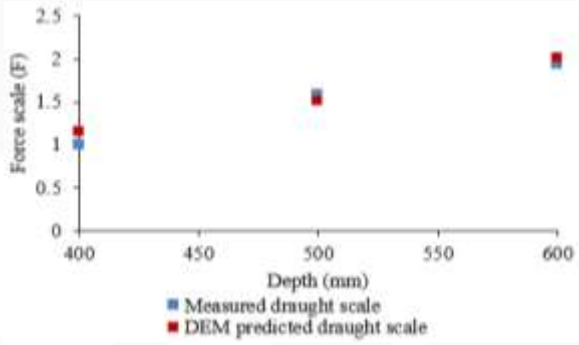
To quantify the proportion of particles incorporated at different depths, the tillage depth was divided into six 100mm horizontal layers and the percentage of particles (DEM) and pixels (test image) in each layer were calculated.



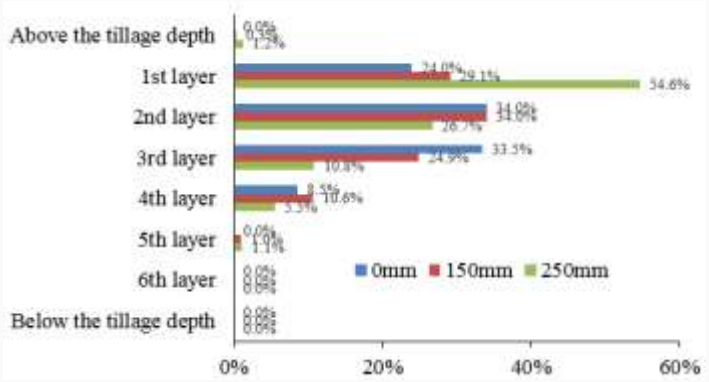
400m

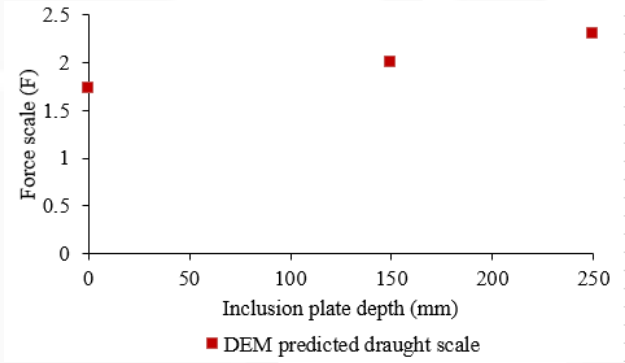


600m

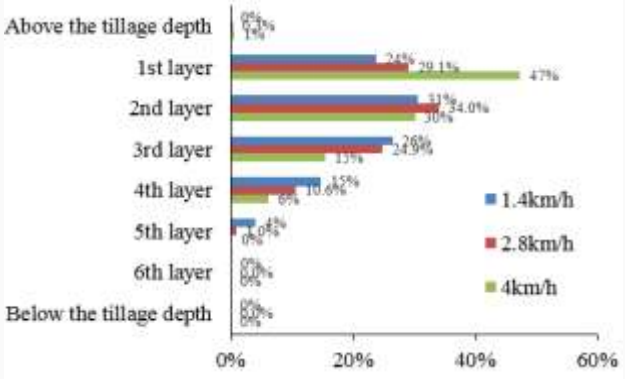


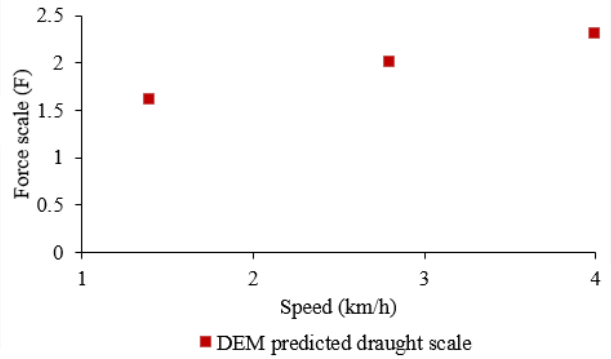
Effect of inclusion ripping depth on top soil incorporation and draft force at 150mm inclusion plate depth and 2.8 km/h speed





Effect of inclusion plate depth on top soil incorporation and draft force at 600mm ripping depth and 2.8 km/h speed





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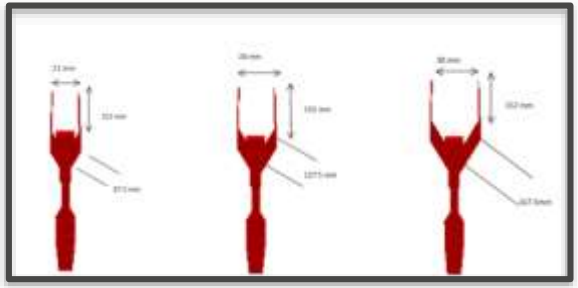
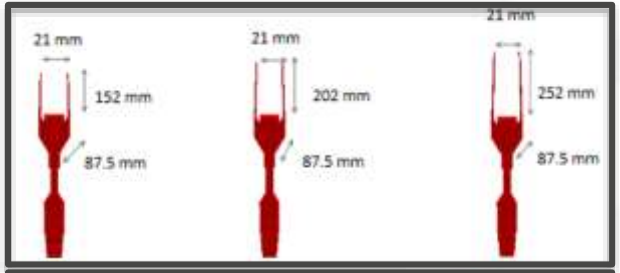
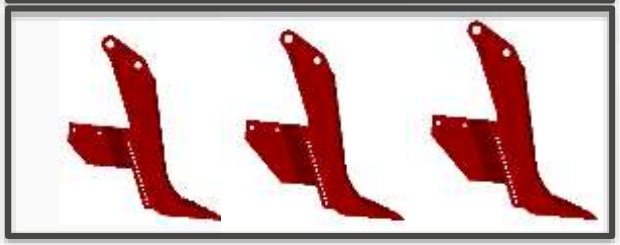
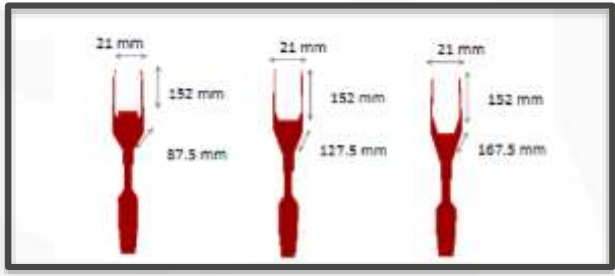
Effect of speed on top soil incorporation and draft force at 600mm ripping and 150 mm inclusion plate depth

Further work is currently being undertaken to investigate effects of geometry parameters on draft forces and top soil burial

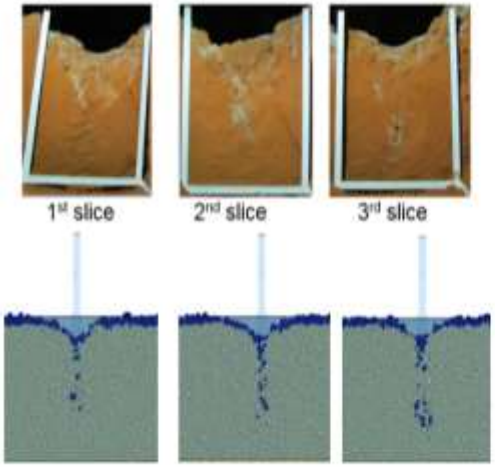




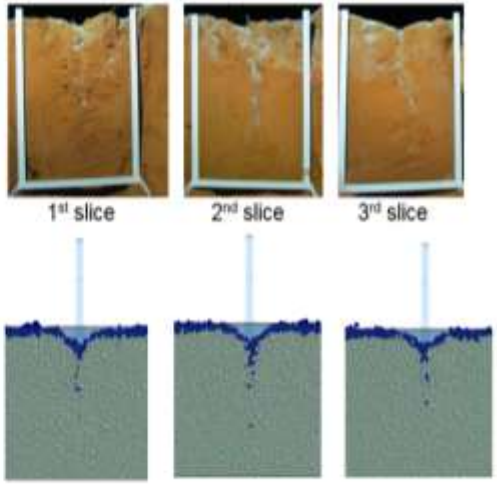




600mm Deep @ 3km/h



600mm Deep @ 3km/h



600mm Deep @ 5km/h

600mm Deep @ 5km/h

KEY MESSAGES

- Increasing ploughing speed from 5-15km/h significantly decreases the depth of topsoil burial
- Increasing ploughing depth beyond 200mm removed more topsoil from the surface but does not have a significant effect on the depth of topsoil burial
- The correct use of skimmers on mouldboard ploughs can increase the amount of topsoil burial below 100mm depth
- Faster forward speeds lead to less uniform mixing with ‘hot-spots’ of concentration within a spaded profile.
- Field research is required to identify which soil amendment incorporations (e.g. lime, clay, organic matter, fertiliser, etc.) can benefit from uniform spading in terms of crop response, and when less uniform (= lower cost) spading is adequate for sandy soils.

KEY MESSAGES

- Increasing ripping depth, whilst keeping the inclusion plate depth constant, does not increase the inclusion of topsoil but increases the draft force
- More effective topsoil incorporation is achieved at slower ripping speeds
- There is potential for improved inclusion plate design to reduce draft and improve top soil inclusion.

Thank you - Questions?

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