Improving the adoptability of spading practices in constrained sandy soil environments

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Abstract

With increasing adoption of sandy soil amelioration practices such as spading, minimising the risks of soil erosion post-operation is of paramount importance. Solutions being researched include developing effective and practical ways to i) keep surface residue in spaded paddocks and/or ii) reliably establish a vigorous (cover) crop as quickly as possible after spading. One-pass 'spade and sow' approaches have been developed and evaluated to effectively address the challenges of early crop establishment and problems associated with subsequent sowing in soft spaded soil. 'Strip spading' concepts are also being evaluated whereby strips within a paddock are spaded in turn over a cycle of two to three years to gradually ameliorate the constrained area, leaving residue protection in unspaded zones each season. At the paddock scale, 4.5 m wide spading of harvester trail strips incorporates concentrated crop residue as organic input, as well as weed seeds, achieving clear benefits in soil water use and grain yield. At the machine scale, modifications can be made to spade and sow 350mm wide strips every 700mm, leaving bands of surface or standing stubble between emerging crop rows. This evaluation work conducted across a variety of projects is on-going.

Keywords:

Spading, spade and sow, strip-spading, sandy soils, soil erosion, soil amelioration

Introduction

Options for sandy soil amelioration in the Southern and Western grain cropping regions of Australia rely on intensive strategic tillage interventions, many of which leave the soil profile loose, soft and exposed. These often once-off interventions include inversion ploughing, delving and mixing by high speed tined implements or rotary spading. In many regions, the adoption of such full soil disturbance operations is limited due to the high risk of soil erosion until a crop is successfully established, the challenges of securing accurate seed placement and leaving a uniform surface finish, which typically result in erratic and poor primer crop establishment. In recent years, rotary spaders have been promoted as effective mixing tools able to operate at depths up to 400 mm and producing very significant grain yield responses in a variety of sandy soil contexts (Fraser et al. 2016).

Specific design adaptations such as larger rear press-wheels (Figure 1) leaving a consolidated profile with treaded furrows, have been made to reduce the impacts of soil erosion. This paper reports on the results of innovative techniques aiming to increase the farming system benefits and reduce the risks of erosion to a minimum, as a pathway to boost the adoptability of rotary spading in constrained sandy soils.

"Spade and sow" in one pass

The risk of soil erosion following spading increases rapidly with the amount of time that the sandy soil is left bare and without an established crop.

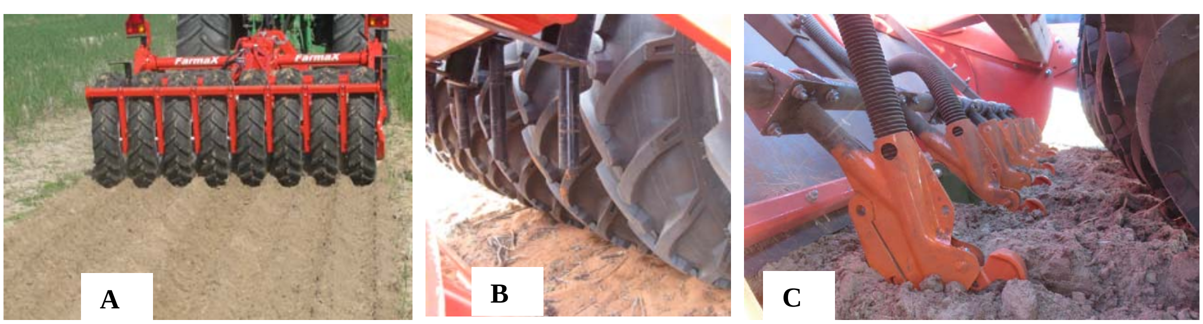

Figure 1: A: lugged tyre press-wheels modified for imported spaders for the Australian market, B: example broadcast tubes of early adaptation dropping seed/fertiliser in front of the wheels, C: improved seeding kit using European style *suffolk* coulters on a floating bar to improve seed placement and germination reliability.

To reduce this period of erosion risk and make use of subsoil moisture that is typically brought up to the surface during the spading process, seeding capabilities directly behind the spader ("spade and sow") have been developed by some adopting farmers and contractors with some success (Figure 1, B).

In 2018, an improved seeding system solution (Figure 1, right) was developed for a research dedicated spader and evaluated under GRDC project CSP00203.

Figure 2: Barley crop established with an opener kit in a 'spade and sow' operation at Carwarp,

Spartacus barley was sown in a replicated trial at 50 kg/ha by the two kits under a 'spade and sow' operation on 7 June 2018 in a red sand at Carwarp, Victoria. The soil was moist at sowing and 8 mm rainfall was received over the four days after sowing. Plant density improved by 45% with the opener kit compared to the broadcast kit at 43 days after sowing (Table 1). A significant proportion of seeds were left on the surface under the broadcast kit, achieving a 13mm shallower seeding depth, while the variation in seeding depth under the opener kit was greater due to the impacts of tyre lugs contributions on soil cover and the additional floating feature of the kit (Table 1). Vigorous crop types are advisable when establishing primer crops.

Table 1: Evaluation results of two sowing kit options under a 'spade and sow' operation (Carwarp, Vic, 2018)

	Plants/m^2 (±s.e.)	Field losses*	Mean seeding depth (±st.dev.)
Opener kit	110 ±6.5	12%	32 mm (±11.6mm)
Broadcast kit	76 ±7.5	39%	19 mm (±8.3mm)

*based on 38 g/1000 sample and 95% germination test

Strip spading of header trails:

Maximising the benefits of spading with organic matter

The spading of organic matter into the top 400mm was extremely beneficial at three South Australian (SA) Mallee sandy soil sites in 2014 and 2015 seasons. At the New Horizon trial site in Karoonda in 2014 receiving below average 174mm growing season rainfall (GSR), spaded lucerne pellets produced a yield increase of 1.1 t/ha over the control (0.5t/ha). In a nearby demonstration site established in the following dry year (169mm GSR), 6 and 9 t/ha spaded chicken manure yielded 3.3 t/ha, while spading alone achieved 2.2 t/ha and the control plot yielded 1.6t/ha (McDonough 2016). At a demonstration site at Waikerie in 2015 (153mm GSR), the control yielded 1.3 t/ha, while the 3 and 6 t/ha spaded chicken manure yielded 2 t/ha and 2.1 t/ha respectively, in the first year. Where these same rates of chicken manure were spread on the surface without spading, they yielded up to 0.6 t/ha less than when spaded. At both sites, these treatment yield trends continued in following seasons including the decile 1 season of 2018. Fraser et al. (2019) have shown various on-going benefits of spading into their 5th year at three New Horizon sites in SA. The reasons for the longer term benefits at these various sites were identified as follows:

Breaking compaction. Soil compaction in the 200-400mm depth layer was evident from cone penetration investigations at spaded sites and quantifying the physical benefits of loosening by spading (data not shown). In soil pits observations conducted in October under control plots, there was wet soil and no root growth in these layers. In contrast, the spaded plots showed root growth down to the clay layer, drying the soil to 1 m and 1.5 m depth at the Karoonda and Waikerie sites, respectively.

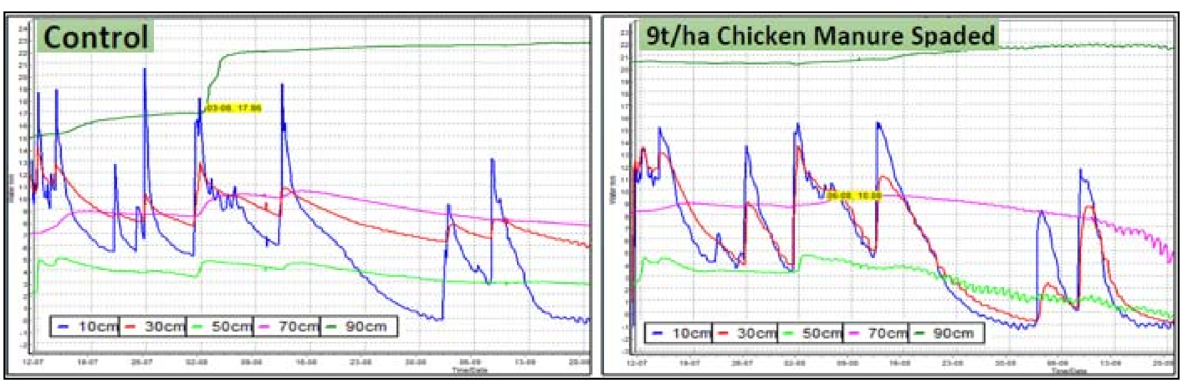

Figure 2: Soil moisture probe readings (mm) at 5 depth layers at the Karoonda site (July-Sept 2015)

Increased soil moisture retention and utilisation**.** The addition of organic matter through the profile to 400mm held vital rainfall within this main crop root zone, rather than quickly draining through to become unavailable in the deeper compacted layer. This sand compaction has contributed to ground water recharge and seeps developing lower in the landscape. Soil moisture probe results (Figure 2) under control plots show soil moisture quickly spikes from rainfall events, with evidence of water recharge down to 900mm depth. The crop only draws moisture down to wilting point in the surface layer. By contrast, the spaded chicken manure shows soil moisture is clearly retained and used by the crop in both the 100mm and 300mm layers and crop roots beginning to draw moisture down at 700mm depth, with no recharge seen at 900mm

Improved fertility, nutrition and soil health. Chicken manure is available locally at a cost of $30/t delivered, with each tonne containing approximately 30 kg of nitrogen (N) and 8 kg phosphorous (P), as well as other nutrients. Deep soil tests conducted the season after amelioration (May 2016) at Karoonda revealed that spading alone had 27 kg/ha less N to 600mm depth than the control (due to N export from the higher yields in 2015), and yielded 5% lower as a result. By contrast, the 6 and 9 t/ha spaded chicken manure plots revealed similar soil N levels to the control (despite exporting an extra 140 to 150 kg/ha N in 2015 yields), and still went on to yield an extra 1.4 t/ha and 1.9 t/ha more, exporting and additional 65 to 85 kg/ha N in 2016. This suggests that the manure continued to mineralise and supply nutrition to the crop during that season. The farmer will need to apply additional nutrition over these ameliorated sandy soil zones according to increased yield potentials to maintain these yield benefits.

Despite these excellent spading manure results that have also produced gross margins that pay for treatment costs within 1 to 2 years, there remains a strong resistance among low rainfall zone farmers towards adopting these practices. This resistance is due to high wind erosion risks created on very vulnerable soil types, which can take many years to rehabilitate if degraded by strong autumn winds prior to crop establishment.

Innovative approach: Strip-spading of concentrated header residue trails

One enterprising family (Haywards) at Lameroo, SA has attempted to overcome this issue using a strategy of only spading their header residue strips. They operate a 12m wide harvester and concentrate the header residue within 4.5 m strips to match their spader width. Over following seasons, the harvester trail is moved across to enable the complementary spading of previously undisturbed strips of soil, and in the process provide three years of associated burial of weed seeds such as ryegrass and brome grass (SAGIT 2017).

Figure 3. A: Erosion of fully spaded sandhill (Inset shows depth of fine sand accumulated from erosion in swale below); B: spaded header trials over same sandhill across adjacent paddocks at Lameroo (April 2016).

Evidence of the reduction of weeds was variable at different sites, but where it has been most dramatic (up to 90%), the impact of increased weed competition from improved cereal growth, rather than only weed seed burial, was having the greatest impact over 2 seasons monitoring. Recent analysis of the mechanics of layer mixing by spading suggests that not all weed seeds would be effectively buried (Ucgul et al. 2019). A key benefit of this approach is the protection of the 4.5 m spaded strips afforded by the unspaded areas in between. In a telling demonstration of such benefits (Figure 3), the erosion damage under a fully spaded sandhill resulted in up to 50mm of fine sand deposited on the swale below, compared with very minimal sand movement with spaded header trails only over the same sandhill in the adjacent paddock. The three year process of header trail spading to ameliorate a sandy soil area is also a way to incorporate three times the levels of available crop residue concentrated by the header (12 to 24 t/ha) compared to spading the entire paddock. Cereal growth has greatly increased in the spaded header trail rows in the loamy flat soils within these paddocks. However, very dry springs in 2017 and 2018 has not converted this high crop biomass into increased grain yield. Spading depth in reduced on the heavy textured soils to prevent sodic subsoil clay being mixed into the surface, as this had previously led to poorer crop establishment. Adding additional N, P, sulphur and zinc fertilisers to header trails prior to spading is a simple way to emulate the proven long term effects of spaded animal manures, initially countering N tie-up from high C:N ratio residue while in the longer term cycling nutrients in support of higher yield potential.

Small scale strip spading:
At a machine scale, a rotary spader can be modified to spade and sow narrow strips within its operating width. This concept is being evaluated at the University of South Australia using a 2.15 m Farmax *Profi* research spader modified to spade three 350mm wide strips and leaves bands of stubble cover in between (Figure 4). The opener sowing kit previously developed to evaluate 'spade and sow' operations is currently being adapted to evaluate 'strip-spade and sow' operations. This approach would aim to spade a targeted area over a cycle of two years while aiming to establish crops over the spaded strips each year, before returning to a normal seeding practice thereafter. Field evaluation is currently underway.

Figure 4. A: 350mm strip spader prototype kit being developed at the University of South Australia using six half blades (Inset shows blade configuration) and two shields per strip coupled with a dual opener sowing kit per strip; B: effect of strip spading in the field (courtesy of Farmax Metaaltechniek BV)

Conclusions
Several research and demonstration activities in constrained sandy soils are focussing on improving the adoptability of amelioration practices via spading. Results to date show it is possible to improve control over soil erosion risks in spaded areas by directly sowing at the time of spading, using improved seeding opener kits to maximise crop establishment performance in order to stabilise the vulnerable sand. It is also possible to modify a spading machine to only spade half its working width, in distinct narrow strips and leave undisturbed areas with surface residue in between, as well as 'strip-spade and sow' in one pass. An innovative approach to spade strips on harvester trail areas with concentrated crop residue has demonstrated clear grain yield and soil water use benefits. Over a cycle of three years, this practice aims to ameliorate a full paddock and represents an inventive pathway to optimise subsoil amelioration with farm grown biomass.

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