Gross soil modification of duplex soils through delving and spading

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Abstract
Duplex soils in South Australia present a number of constraints that have been observed to reduce root growth and plant yield. This paper investigates two soil modification processes that have been developed to mix soil horizons, thus reducing the impact of some subsoil constraints. One technique is called "clay delving", and involves using a specially designed ripping tine that peels clay from the B horizon, through the A horizons to the surface. The other technique is called "Spading" and involves the use of a "spader" machine. This machine uses a series of off-set, rotary "spades" to mix the surface horizons to a depth of approximately 30-40cm.

Both soil mixing procedures have been used to bring up and mix in clay from the B horizon, as well as to mix in surface materials such as hay, green manure crops, surface applied clay, lime and gypsum. Trial data gathered from measuring changes in the soil, as well as measured changes in plant yield are presented from 2 field trials. Significant improvements in subsurface and subsoil root growth have been observed, and plant dry matter growth has been recorded to improve considerably.

Key Words
Bleached, waterlogged, infertile, root abundance, soil morphology, yield.

Introduction
Soils with duplex (Northcote 1979) properties often present restrictions to plant root development (Hall *et al.* 2009). Investigations into methods that significantly alter the condition of the upper profile in duplex soils have indicated that the performance of crops and pastures could be improved (Groocock pers. comm.; Bailey unpublished data). A significant amount of research has been undertaken to investigate the potential for improving sandy soils by working dispersive clays to the surface horizon (Ma'shum *et al.*1989; Cann 2000).

This paper presents findings from a pair of trials that further modify the soil by mixing the horizons of the upper profile through the use of a "spader" machine, and through a technique known as "clay delving". Clay delving is described in detail in Desbiolles *et al.* 1997, and involves using a specially modified ripping tine, a metal prong that peels clay from the B horizon, through the A horizons to the surface. "Spading" using the spading machine uses a series of off-set, rotary "spades" to mix the surface horizons to a depth of approximately 30-40cm. Both soil mixing procedures have been used to bring up and mix in clay from the B horizon, as well as to mix in surface materials such as hay, green manure crops, surface applied clay, lime and gypsum. Some of the data gathered from measuring changes in the soil, as well as measured changes in plant yield are presented here.

Methods
Sand over clay site on the Fleurieu Peninsula (south of Adelaide)
The soil at the Fleurieu Peninsula site was classified as a Brown Sodosol (Isbell 2003), and had a thick sandy A horizon with a strongly bleached A2. The B horizon was a coarsely structured and mottled clay. The A2 horizon presented indications of being highly infertile, and of having been subject to frequent seasonal waterlogging from water perched on the sodic clay sub-soil.

The trial treatments were established between 10th March and 5th May 2009. The trial design comprised 80m long by 15m wide strips of each treatment, placed parallel to each other within the paddock. The trial was divided into 3 replicates. Within each replicate, the 4 treatments were randomly allocated. The treatments comprised a control, a treatment with one pass of the spader machine, a treatment with one pass of a clay delver, and a treatment with one pass of a clay delver followed by one pass of a spader machine. The site was sown to Triticale on 14th June 2009. Dry matter cuts made on 10th September 2009. Each plot had ten cuts made to assess dry matter production, with each cut being 1 meter long by a single plant row wide. A total of

30 cuts per treatment were made. Samples were dried until no more weight was lost at 40°C in a drying oven, then weighed. Soil profiles were excavated within each treatment on 7th October 2009, with observations made regarding soil morphology and root distribution.

Loam over clay site near Naracoorte (in south eastern SA)
The soil at the Naracoorte site was classified as a Brown Chromosol (Isbell 2003), and had a thick, light sandy clay loam (Northcote 1979) A horizon with a paler A2 that contained significant amounts of ironstone gravel. The A2 horizon presented indications of some degree of seasonal waterlogging from water perched on the clay sub-soil.

The trial treatments were established between 22nd April and 6th May 2009. The treatments comprised a control, a treatment with one pass of the spader machine, and a treatment with one pass of a clay delver followed by a single pass of off-set discs. The trial design comprised plots of 10m times 15m, with 4 randomly allocated reps of the control, and 8 randomly allocated reps of each of the other 2 treatments. The site was sown to Barley on 17th June 2009. Dry matter cuts were made on 14th October 2009. Each plot had one cut made to assess dry matter production, with each cut being 0.5 of a meter long by a single plant row wide. A total of 4 cuts were taken from the control plots, and 8 cuts from the other 2 treatments. Samples were dried until no more weight was lost at 60°C in a drying oven, then weighed.

Results

Sand over clay site on the Fleurieu Peninsula
The changes in soil morphology are illustrated in Figure 1. The spading has mixed the A1 and A2 horizons to a depth ranging from 30-35cm. The delving has produced some mixing of clay into the A1 and A2 horizons, and significant mixing of sandy material to a depth of about 60cm into the B2. Root abundance in the A2 of the control was classified as "few" (McDonald *et al.* 1990), while the root abundance in the portion of the A2 modified by spading, and the A2 and B2 modified by delving, portrayed root abundances of "common to many" (McDonald *et al.* 1990).

Figure 1. The left hand profile illustrates the control soil, the middle profile shows the effect of spading, and the right hand profile shows the impact of clay delving.

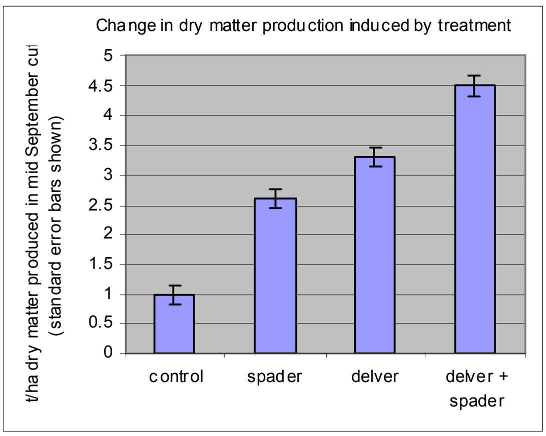

Figure 2. Plant productivity responses to the soil modification treatments.

Dry matter cut from the crop at mid-September showed large improvements in plant growth as a response to the soil modification processes implemented. Table 1 and Figure 2 present the mean results from the dry matter cuts made of the treatments in September 2009, and the means are presented with error bars generated from the standard error.

Table 1. Plant productivity responses to the soil modification treatments.

Treatment	Mean t/ha	Standard deviation
control	1	0.4
spader	2.6	1.1
delver	3.3	1.4
delver + spader	4.5	1.8

Loam over clay site near Naracoorte, SA

Significant changes in surface soil condition were observed, including clay brought to the surface in the delved plots, and paler A2 material and large amounts of ironstone gravel in the spader plots. Excavations were not made to observe subsurface and subsoil changes in soil morphology and root distribution.

Figure 3. A photograph of the soil surface of a delved plot taken 26th June 2009, illustrating the clay worked into the soil surface.

Dry matter cut from the crop at mid-October showed significant improvements in plant growth as a response to the soil modification processes implemented. Table 2 and Figure 4 present the mean results from the dry matter cuts made of the treatments in October 2009, and the means are presented with error bars generated from the standard error.

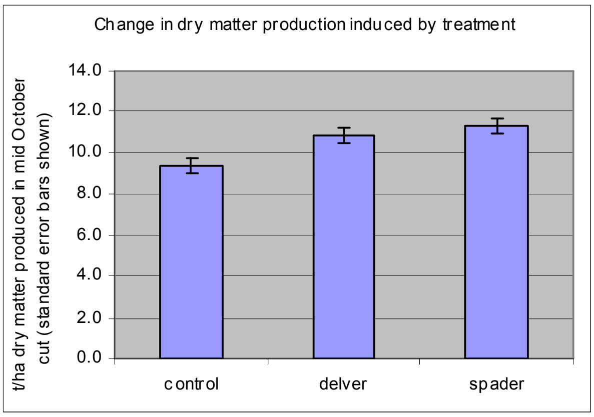

Figure 4. Plant productivity responses to the soil modification treatments.

Table 2. Plant productivity responses to the soil modification treatments.

Treatment	Mean t/ha	Standard deviation
control	9.4	1.5
delver	10.8	1.1
spader	11.3	2.1

Conclusion

Both the spader machine and the clay delving process grossly altered the morphology of the two soils investigated. The spader machine appeared to improve the condition and root abundance of the upper A2 horizon, while the clay delving appeared to improve root development well into the clayey B horizon. Early growth results appear to confirm previous anecdotal evidence, that modifying texture contrast soils through the mixing of the surface horizons significantly improves plant productivity. The large increases achieved include changes to weed populations and disease incidence, as well as the observed root growth and soil modification changes. Consequently, monitoring over time will be required to determine the long term response to the soil morphological changes.

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