Understanding the amelioration processes of the subsoil application of amendments

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Wagga Wagga Agricultural Institute
Saline, Sodic, Magnesic or All of the Above?

Surface crusting & dispersive soils

Impacts of dispersive clay
- surface crusting impacts on seedling emergence

Fine particles form a crust
How do soils become sodic

Legend

<table>
<thead>
<tr>
<th>Ion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>Sodium chloride (salt)</td>
</tr>
<tr>
<td>Na</td>
<td>Sodium</td>
</tr>
<tr>
<td>Cl</td>
<td>Chloride</td>
</tr>
<tr>
<td>Ca</td>
<td>Calcium</td>
</tr>
<tr>
<td>●</td>
<td>Clay particles</td>
</tr>
</tbody>
</table>

Salts, chloride and calcium are washed down into the soil leaving sodium in the surface layers bound to clay particles.
### Transformation of subsoil structure

<table>
<thead>
<tr>
<th>Control</th>
<th>30-40 cm</th>
<th>Subsoil manure 30-40 cm</th>
</tr>
</thead>
</table>

- Amelioration can transform the subsoil
- Potential increase grain yields by up to 70%
Poor water use efficiency

Different environments; Different Constraints

Common problem
Soil physicochemical & nutritional constraints = poor WUE
↓ yields; reduced profitability; > offsite impacts

NSW Government
Department of Primary Industries
Wheat farm yield and water-limited potential yield

- Effective use of water stored deep in the soil profile
- Management of subsoil constraints
- 10.5 mm of additional subsoil water = extra 0.62 t/ha
Site characteristics: SNSW

- Carbonate and bicarbonate toxicities
- Dispersion
- Salinity
- Osmotic stress
- Poor structure
- Waterlogging
- Elemental toxicities
- Dispersion
<table>
<thead>
<tr>
<th>Treatments</th>
<th>Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Deep gypsum</td>
<td>5 t/ha</td>
</tr>
<tr>
<td>Deep liquid NPK</td>
<td>N&amp;P to match DAP @ 80 kg/ha</td>
</tr>
<tr>
<td>Deep manure</td>
<td>8 t/ha</td>
</tr>
<tr>
<td>Deep pea straw</td>
<td>15 t/ha</td>
</tr>
<tr>
<td>Deep pea+ gyp+ NPK</td>
<td>15 t/ha, 5 t/ha, 80 kg/ha</td>
</tr>
<tr>
<td>Deep pea+ NPK</td>
<td>15 t/ha, 80 kg/ha</td>
</tr>
<tr>
<td>Deep wheat</td>
<td>15 t/ha</td>
</tr>
<tr>
<td>Deep wheat+NPK</td>
<td>15 t/ha, 80 kg/ha</td>
</tr>
<tr>
<td>Rip only</td>
<td></td>
</tr>
<tr>
<td>Surface gypsum</td>
<td>5 t/ha</td>
</tr>
<tr>
<td>Surface manure</td>
<td>8 t/ha</td>
</tr>
<tr>
<td>Surface pea</td>
<td>15 t/ha</td>
</tr>
</tbody>
</table>
2017 trial
Amelioration of subsoil sodicity improves yield, 2018

Wheat grain yield (t/ha)

- Rip only
- Deep nutrients
- Deep pea hay+nutrients
- Surface gypsum
- Surface manure
- Surface pea hay
- Control
- Deep manure
- Deep wheat stubble
- Deep wheat stubble+nutrients
- Deep pea hay
- Deep gypsum
- Deep pea hay+gypsum+nutrients

Wheat, Lancer
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Wheat Grain Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rip only</td>
<td>0.0</td>
</tr>
<tr>
<td>Deep nutrients</td>
<td>0.5</td>
</tr>
<tr>
<td>Deep pea hay + nutrients</td>
<td>1.0</td>
</tr>
<tr>
<td>Surface gypsum</td>
<td>1.5</td>
</tr>
<tr>
<td>Surface manure</td>
<td>2.0</td>
</tr>
<tr>
<td>Surface pea hay</td>
<td>2.5</td>
</tr>
<tr>
<td>Control</td>
<td>3.0</td>
</tr>
<tr>
<td>Deep manure</td>
<td>0.0 ± 0.5</td>
</tr>
<tr>
<td>Deep wheat stubble</td>
<td>0.5 ± 0.5</td>
</tr>
<tr>
<td>Deep pea hay</td>
<td>1.0 ± 0.5</td>
</tr>
<tr>
<td>Deep gypsum</td>
<td>1.5 ± 0.5</td>
</tr>
<tr>
<td>Deep wheat stubble + nutrients</td>
<td>2.0 ± 0.5</td>
</tr>
<tr>
<td>Deep pea hay + gypsum + nutrients</td>
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</tr>
</tbody>
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Amelioration of subsoil sodicity improves yield, 2018

53%
Amelioration of subsoil sodicity improves yield, 2017

Barley, LaTrobe

27%
Top performing treatments so far

Increasing relative grain yield (% of control)

Deep Pea

Deep pea+gypsum +nutrients

2017

2018
Deep wheat stubble
Deep wheat stubble + nutrients
Deep gypsum

Increasing relative grain yield (% of control)

Interesting results…!
Crop responses to amelioration of subsoil constraints Sep 2018

Ameliorated subsoil

Control

Subsoil amelioration
Control treatment
Yield improvement is associated with increased subsoil water uptake

In average ~10-15% Extra subsoil water use
Yield improvement is associated with the changes in soil properties

Tavakkoli et al. Net dispersive charge, a new concept for dispersive soils. EJSS. 2016

Yield improvement is associated with the changes in soil properties.

Soil structure

4-fold increase in soil structure

Control  gypsum  OM  OM+gypsum  OM+nutrients

Aggregate stability (mm)
Summary

Outcome:

• Deep placement of organic amendments and gypsum significantly increased yield

• Mechanisms:
  i) reduction in net dispersive charge and pH
  ii) enhanced microbial biomass C
  iii) additive effect to give 4-fold enhanced aggregation
  iv) at field level demonstration of increased PAW therefore addressing yield gap
Know your soil…
Saline, Sodic, Magnesic or All of the Above?

- Deep soil testing at meaningful intervals

<table>
<thead>
<tr>
<th>Sampling for</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (Water)</td>
<td>1:5 in water</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>1:5 in water</td>
</tr>
<tr>
<td>Exchangeable cations (CEC)</td>
<td></td>
</tr>
<tr>
<td>ESP</td>
<td>Calculated from CEC and exchangeable cations</td>
</tr>
</tbody>
</table>

![Soil chemistry diagram with clay particle and ions]
Soil development and organic matter chemistry

Direct evidence for microbial-derived soil organic matter formation and its ecophysiological controls

Kallenbach et al. Nature Communications (2016)
Yield improvement is associated with increased subsoil water uptake.

Water content (neutron probe activity)

Depth (cm)

Control

Deep pea hay + gypsum + nutrients

Control

Deep manure

Control

Deep pea hay

Control

Deep nutrients

Control

Deep ripping only

Control

Deep gypsum

GRDC

NSW GOVERNMENT

Department of Primary Industries
Yield improvement is associated with the changes in soil properties
Yield improvement is associated with increased subsoil water uptake.

Water content (neutron probe activity) for different treatments:
- Deep pea hay + gypsum + nutrients
- Deep pea hay
- Deep nutrients