Crop nutrition and the response to claying of sands

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Key messages

- Subsoil clays used for clay amendment of sands vary greatly in properties.
- While addition of subsoils with > 100 mg Colwell K/kg overcomes K deficiency and boosts crop yields on sands with low soil test K, in cases where Colwell K was < 50 mg/kg in the subsoil added, there are no yield responses.
- Testing subsoils for key properties best ensures a positive response to investment in clay amendment.

Aim

The aim was to determine how claying of sands alters crop nutrient management.

Methods

Clay Soil Pit Survey

Subsoil samples were collected from clay pits that had been used by farmers to remediate non-wetting sands and also from farms where claying and delving were being investigated. Most of the subsoil samples were from the south coast of WA, where claying and delving have been more widely adopted. Subsoil samples consisted of multiple sampling points at the same depth within each pit. The location of the pit and depth sampled were recorded. The soil properties measured included clay content, nutrients (N, P, K, S, Cu, Zn, Mn, Fe), nutrient availability and retention (Cation exchange capacity, organic carbon, phosphate buffering and retention indices - PBI, PRI) and potential toxicities (B, EC, pH). Soil chemistry and particle size were analysed by the CSBP Laboratories (Bibra Lake, Perth). More than eighty samples were collected and analysed. The mineralogy of selected samples was analysed by X-ray diffraction through the State Chemistry Laboratories and the University of WA.

Field Experiments and Demonstrations

Existing claying trials and demonstration sites were also assessed as part of the research enabling in-field impacts of varying clays on soil and crop nutrition to be assessed. Measurements were made on two long-term experimental sites:

1) Clay rates by incorporation experiment at Dalyup. Site was established by WANTFA in 1999 with ongoing monitoring by DAFWA. Clay was applied at rates of 50, 100, 200 and 300 t/ha.
2) Long-term claying site at Esperance Downs Research Station (EDRS). Established in 1998. Clay-rich subsoil was spread at 0, 50, 100 and 150 t/ha and incorporated with a scarifier.

A further five more recently established experimental and demonstration sites were also assessed:

1) Clay by depth of incorporation at EDRS. Established in 2012 by DAFWA. In this replicated plot experiment clay was spread at 175 t/ha and incorporated either shallow (15cm) or deep (35cm) using a rotary spader.
2) Clay rate by incorporation method at Bolgart. Established by WANTFA and Wheatbelt NRM in 2010. DAFWA assisted with ongoing monitoring and assessment of the site. Clay was applied at three rates 0, 260 and 520 t/ha. Incorporation tools included offset discs, rotary hoe and rotary spader.
3) Clay delving and spading demonstration, Bolgart. Established as a replicated experiment by landholder and WANTFA in 2013. The treatments were: no-till (the current system); spading alone; delving followed by spading. Lime rates were also added at 0, 2, 4, and 8 t/ha before delving and spading treatments to test their role in subsoil acidity treatment, but these results are not presented here.
4) Clay rates by incorporation demonstration, Badgingarra Research Station (BRS). Established by DAFWA and West Midlands Group in 2009. Clay applied at 5 rates, 0, 50, 100, 360 and 450 t/ha and incorporated with either a rotary spader or shallow working (10 cm) offset discs.
5) Water repellent soil amelioration experiment, BRS. Established by DAFWA in 2009, soil amendment treatments were nil amendment, lime at 3 t/ha and clay at 150 t/ha. Across these strips a range of tillage and incorporation treatments were applied, including offset discs, deep ripping and rotary spading.

Pot Experiment
A soil incubation experiment and two glasshouse pot trials were designed. The aim of the incubation experiment was to examine the availability of K on a range of clays with different K contents added as powders to a range of sands. The aim of first pot trial was to determine the effect of addition of low K (102 mg Colwell K/kg) and high K (872 mg Colwell K/kg) clays as a powder to sands with and without added K fertiliser to determine effects on maize growth and K uptake. In a second pot trial, the aim was to determine the effect of aggregate size of subsoil clay mixed into sands on uptake of K by wheat.

Results

Bolgart
Two field experiments were completed at Bolgart, 130 km NE of Perth: clay incorporation methods; delving/ spading.

Clay addition (520 t of subsoil/ha) in the Bolgart experiment increased yields in 2010 and 2011, but not at 260 t/ha or in any of the following four years. Indeed, in 2014, there was negative effect of clay addition on yield of lupin. At the Bolgart site, the low MED value in 2013 suggests that water repellence was not a constraint in later years of the experiment even though clay content in the 0-30 cm layer was only 1.5-2.5 %.

At the Bolgart clay experiment, there was no obvious benefit of clay amendment for K concentrations in sands or in crops. In 2014, clay treatment appeared to decrease the concentrations of K in lupin leaves. The subsoil added at Bolgart contained 32-63 mg Colwell K/kg and apparently contributed negligible plant available K. Even after 5 years, with annual K fertiliser applications of 13 kg K/ha, there was no indication that clayed soils either contained more plant available K or supplied more to crops probably because the annual K additions were only sufficient to replace what would be removed by 2-3 t of wheat grain/ha.

Clay addition without incorporation decreased crop yields in the first 2 years, and even in year 5 continued to do so. This reinforces the learning from clay application elsewhere that thorough incorporation of subsoil clay is necessary to maximise benefits.

Badgingarra

Two field experiments were studied at Badgingarra, 220 km N of Perth.
In five crops harvested since the Badgingarra clay rates experiment started in 2009, clay addition had no significant effect on crop yields. The site had low levels of water repellence when assessed in 2013. The subsoil used at Badgingarra was low in K (26-36 mg Colwell K/kg). However, the sand to which clay was added in the clay rates experiment had more than adequate extractable K. Hence, in that experiment there was little influence of clay addition on crop K nutrition. Flag leaf analysis confirmed that wheat K status was adequate. While the sand on this site had Colwell P levels in the marginal range of grey sands, there was no consistent effect of clay addition or rate on Colwell P values in the 0-10 cm layer.

At the lime, clay and incorporation experiment, clay had positive effects on yield in 2013 and 2014. Even through the same subsoil material was used as the clay rates experiment, the soil test values at the experiment were lower in Colwell P and K than the clay rates experiment. With addition of clay, Colwell K was increased from 39 mg/kg, which is considered deficient for cereal crops, to 52 mg/kg which is adequate. Hence the alleviation of K deficiency may explain the increase in crop yields with clay addition, but soil P levels remained deficient. The increase in yield with clay addition was consistent with an increase in flag leaf K from 1.3 % K which is deficient to 1.5 % K which is close to adequate.

Clay pit survey

A high degree of variation in clay content was found among the clay samples collected. Approximately one-tenth of subsoil samples had clay contents less than 25% which would be of doubtful value for clay amendment. The PRI levels in the subsoil clays were higher than topsoil samples. This suggests that some degree of P retention would occur initially in clayed soils. Experimental results from Mokhtari (2014) and Hall *et al.* (2015) have confirmed this with significantly higher adsorption and P levels respectively in clay-amended soils. The experimental data supports anecdotal reports that farmers increase nutrient levels (N, P) in clay-amended soils (N. Blumann, personal communication). Initially the rationale was that the additional nutrients were required to meets higher demand associated with greater productivity. However, higher levels of P supply may be required initially to offset higher levels of P sorption in clay-amended soils. In the longer term if the clay added retains more P, and prevents P leaching, lower P rates may be possible while maintaining crop productivity.

Esperance field experiments

Three of the four experimental sites resulted in significant yield increases as a result of clay addition. When averaged across all years, the addition of clay resulted in yield increases of 50% (Dalyup- 15 years), 42% (EDRS-E1 4 years), 36% (Gibson 4 years) and 0% (EDRS-W7 5+ years) when compared to the control treatments. The improvements in yields can be attributed in many cases to improvements in crop germination resulting from clay ameliorating topsoil water repellence. However, in many seasons emergence was not affected by clay addition yet grain yield increases still occurred and may be attributed to increased nutrient levels and nutrient retention (CEC) as well as improved water retention found in clay amended soils (Hall *et al.* 2010). The site (EDRS-W7) that did not show any grain yield increase to the addition of clay had 3.6% clay without amendment, was not highly water repellent (MED 1.6) and had soil K levels exceeding 130 mg/kg.

Table 1. Properties of sub-soil materials collected from pits on farms used for claying of sands.

		CEC	Col P*	Col K*	S^+	PRI	B	Mn^	pH
		meq/100g	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	
Topsoil	Average	3.54	17.8	82	19.2	1	1.5	5.1	5.24
Subsoil	Average	9.86	3.6	333	51.4	76.7	5	0.6	6.87
Subsoil	Max	27.6	24.0	1090	337.2	196	20	3.0	8.70
Subsoil	Min	1.57	1.0	19	5.2	11.7	0	0.0	4.70
Subsoil	Stedev	5.24	3	227	56	62.6	5	1	0.99
Subsoil	Co-eff of variation (%)	53.1	97	68	109	81.7	92	109	14
Subsoil	n	87	89	95	93	6	66	79	93

* Colwell Method + KCl method ^ DTPA Method

Clay amended soils had increased N levels in the soil at the long term Dalyup trial site and in plant tissue analysis at EDRS (E1) trial in 2014. Nitrogen levels at the other sites were unaffected by clay addition. However, even with increased N availability and increased N uptake in clay amended sands, the dilution of plant N may reduce concentrations in shoots below levels required for optimum growth and yield. In 2013, for example, leaf N concentrations declined in clay amended sands at Dalyup. Based on the hypothesis that clay amendment was tipping crop growth into N deficiency, a supplementary N treatment was applied in 2014 to canola. The supplementary N increased canola shoot N above the critical concentration and resulted in shoot growth being positively correlated with leaf N. However, there was no effect of the supplementary N on seed yield of canola, possibly because of the prolonged dry spell during August- September 2014, and the low seed yield obtained (0.4-0.7 t/ha).

Soil P levels were increased as a result of clay addition at both long term trial sites at Dalyup and EDRS (W7). P levels in canola tissue samples from the clay+spade treatment were also increased at EDRS (E1) in the third year of the experiment when compared to the control. The higher PRI/PBI values found associated with subsoil clays also indicates that P is more likely to be adsorbed and may even be less available as a result of clay amendment. The consequence of this for crop nutrition will depend on whether soil P levels are above, near or below the critical Colwell P values.

K levels in both soil and plant tissue samples were significantly increased at all sites as a result of clay amendment. At the Dalyup site, the addition of subsoil at rates of 200 and 300 t/ha resulted in soil K levels exceeding the minimum threshold (40 mg/kg). K levels in the clays used at the Dalyup and EDRS (E1) ranged from 350 to 1000 mg/kg. The K concentrations in subsoil of the Dalyup and EDRS (E1) experiments were above average relative to the 85 subsoils analysed from the clay pit survey.

Although S has been found to be generally high in subsoil clay samples along the South coast, the effect of clay amendment on S nutrition was not conclusive. It is likely that low inherent levels, leaching and sorption by added clay determine plant access to S.

In terms of micro nutrients, Cu, Fe, Mn were relatively unchanged in both soil and plant samples across all treatments and experiments. Zn was reduced in soil and plant tissue samples by clay addition in the Dalyup and EDRS (E1) trials. B was increased as a result of clay addition at the Dalyup site and EDRS (E1) sites when compared to the control.

Pot experiments
Addition and homogeneous mixing of powdered clays increased K uptake on both the K-deficient Bassendean sand and the K-adequate Esperance sand. After the addition of K fertiliser, the influence of clay on leaf K, shoot growth and K uptake in shoots largely disappeared. In the case of Bassendean sand that contained deficient levels of extractable K, the additional K increased shoot dry weight of wheat. The low K clay in the present study contained 102 mg Colwell K/kg. The critical Colwell K level for wheat and canola yield is about 40-50 mg/kg. The low K clay was not as low in extractable K as some of subsoils used in this study, for example the Bolgart subsoil that contained 30-63 mg K/kg. There was little evidence of increased K uptake due to clay addition at Bolgart, whereas in the present pot experiment the low K clay that contained 105 mg K/kg was an effective source of K. It was not as effective as the high K clay which contained 872 mg Colwell K/kg. This resulted in a 2-5 fold increase in K uptake into wheat shoots. From the clay pit survey completed on the South Coast region, Colwell K in subsoils used for clay amendment of sands ranged from 19 to 1090 mg/kg.

Table 2. Classification of clayed sites according to soil test Colwell K level in topsoil (0-10 cm), in the subsoil amendment added and the whether there was a crop yield response or not (bold font indicates positive grain yield response, generally 30-50 % increase)

	Subsoil K (mg/kg)	
Topsoil K (mg/kg)	< 50	>50
< 60	Badgingarra 1	EDRS2
> 60	Bolgart Badgingarra 2	**Dalyup** **EDRS1** **Gibson**

Conclusions
Based on 7 field sites where sands were clay amended, there appears to be a positive effect of K in subsoils on crop yield if the topsoil has low initial Colwell K, but not if the initial topsoil has adequate K (Table 2). On soils that already have above 60 mg Colwell K/kg, there were no responses to clay addition.

To maximise the returns on investment, soil testing of the subsoil and the topsoil to be treated is highly advisable before undertaking claying. The key subsoil tests are clay%, EC, Colwell K, PBI/PRI and boron. Subsoil testing can lead to more profitable decisions on which subsoils to select for treatment, and the fields to treat or not treat. In addition, better fertiliser decisions can be made for clay-amended sands, in particular for K nutrition.

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