SOIL AMELIORATION IN ACIDIC, YELLOW EARTHS OF THE WESTERN AUSTRALIAN WHEATBELT WITH SUB-SURFACE COMPACTION & ACIDITY.

Improving Soil Structure, Root Mass & Organic Matter at Depth.

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The Liebe Group conducted a field day on the 26th of September 2013 on the property of Colin & Ruth Cail at Wubin in the eastern wheat belt region of Western Australia. Soil profiles from two backhoe pits in one paddock were inspected to assess the change in soil properties from mouldboard ploughing.

The soil profiles were classified according to Stace et al. 1964 as Yellow Earths, Northcote (1992) as Gn 2.21 – Gradational, acid, A₂ horizon not bleached. Under the Isbell (1996) classification the profile is a ‘Yellow Kandosol’. The A₁ horizon is shallow at approximately 100 mm in thickness. The A₂ horizon layer below the topsoil is over 1.0 metre in thickness and shows evidence of compaction. The decline in organic matter and soil nitrogen levels and corresponding decline in soil structure and productivity in lateritic sand plain soils of WA is documented by Callaghan and Millington (1956). They indicated that in this soil and other soils used for wheat growing around the country, soil organic matter and nitrogen levels declined by 50% in the first 20 years after cultivation creating poor soil structural condition.

In this article, soil amelioration is a term used to describe an improvement in soil structure from the application of mechanical inputs to create a defined pedological system. Soil amelioration is necessary in soils with compaction and acidity issues in sub-surface horizons which restrict root growth. The results of soil chemical tests and use of pH indicator were used to assess the soil chemical conditions of the topsoil and the underlying A₂ horizon. Visual observations on root development, the presence of organic matter and soil structure suggest that soil the topsoil has been effectively ameliorated. The effects from amelioration practices are shallow under no-till farming operations and the effective depth of ameliorated soil is defined by the depth of the air-seeder tine.

![Figure 1. Upper section of a yellow earth profile on Cail's property showing poor profile development.](image)

The soil profiles exhibited very dry conditions and approximately 90% of the crop root mass was found to be restricted to the topsoil layer. This zone has been effectively ameliorated by liming and retaining organic residues from no-till farming. There is no evidence of any amelioration of the subsoil from the leaching of lime.
and there is also no movement of topsoil or organic matter. Figure 1 shows little to no plant roots propagating in the acidic, compacted sub-surface layer. Root growth is prolific in the surface layer shown in Figure 1 which has been disc ploughed creating air space, voids for roots to propagate and an improvement in soil structure.

To ameliorate the soil and improve productivity the plant root system should be as large as possible. A large plant root zone is created by reducing impediments to plant root growth such as compacted layers, poorly drained layers, barriers associated with siliceous or calcareous deposits or poorly aerated layers. Plant roots should exploit as large a volume of soil as possible to facilitate nutrient uptake and provide voids for air and water storage. Achieving the correct structural balance will lead to the growth of more resilient plants.

To enhance the size of the plant root system in this situation, the following must be provided:

1. Suitable soil structure for plant roots to propagate, allowing for nutrient cycling and biological activity.
2. Adequate selection and volume of bulk soil ameliorants, incorporated to the required depth, and
3. Adequate nutrition, supplied at sowing to stimulate root growth and plant development.

It is worth considering mechanical shattering of a yellow earth at a moisture content that is deemed to be relatively dry, to achieve improvements in a plant's root system. Effectively ripping a soil that is relatively dry will alleviate subsurface compaction within the fractured zone and allow topsoil, organic matter and air to move to depth and create improved conditions for plant root growth. This influences the volume of soil occupied by plant root systems and will assist with maintaining a reasonably dry soil profile. The volume of water passing beyond the primary root zone is also likely to be reduced. Figure 2 is an image of a soil in the same region that has been ripped, allowing lupin roots to extend throughout the full mass of fractured soil. There was no evidence of root movement into the compacted zone below 400mm, the ripped section was dry and the crop was healthy.

![Figure 2. Soil fractured from deep ripping around Buntine, WA.](image)

On the Cail’s property the mouldboard ploughed zone was assessed for soil profile improvement. The effective rooting depth had increased from 90mm to 150-180mm corresponding with the depth which the mouldboard plough had inverted. Plant roots were prolific throughout the inverted zone, consisting primarily of topsoil with a light mix of subsoil. The topsoil had been adequately limed prior to mouldboard ploughing using a blend of Lime Sand and Dolomitic Lime. A reasonable level of visual organic material was observed as a result of years of continual no-till farming. The mouldboard plough had not reached the proposed depth of 300 mm as it was intended and had not effectively shattered the underlying subsoil. The mouldboard plough had created positive structural remediation within the zone of inversion to 150-180 mm of depth suggesting that compaction is
limiting production on this soil. There is no evidence of subsoil amelioration as a result of mouldboard ploughing at this site. Figure 3 is an image of a mouldboard ploughed section on Cail’s property.

Figure 3. Site which has been mouldboard ploughed.

**Keys to Effective Amelioration of Soil Profiles Dominated by Coarse Textured Material.**

1. Identification of sub-surface constraints, particularly the compacted A$_2$ horizon. Constraints include slaking (an indicator of low organic matter), dispersion, acidity and weak to massive structure. Comprehensive soil testing for exchangeable cations, aluminium and chloride along with a standard macro-nutrients and trace elements should be obtained. If adverse conditions then the inversion of this soil with the topsoil should be assessed.

2. Identification of the same parameters in the topsoil (A$_1$ horizon). Issues requiring amelioration in the A$_1$ horizon should be made prior to undertaking sub-surface amelioration.

3. Build a volume of organic residue on the soil surface and ensure residues are well distributed throughout the total depth of A$_1$ horizon topsoil.

4. Develop a soil physical amelioration plan that will achieve fracturing at depth. In most sandy soils the use of a deep ripper is likely to be best for providing horizontal soil shattering while maintaining adequate depth.

5. Ripping should be considered while the moisture content of the soil is as low as possible without creating problems with dust and excessive draught. The term ‘optimal moisture content’ is used in engineering to define the moisture level for maximum compaction. The soil should have a moisture content not approaching this level. To test the moisture content of a soil, obtain a bulk density core of soil with a fresh weight, oven dry the soil and obtain a dry weight. The dry weight should be divided by the fresh weight to gain percentage moisture. Ideally the soil moisture content should be less than 5% to achieve fracturing and shattering without compaction.

6. The shank length, design of the point and speed of travel will influence the way soils are fractured.

7. Do not rip soils without an effective plan for soil stabilisation which involves the growth of plant roots and deposition of organic matter at depth.
8. Check to see if coarse sandy soils contain fine sand, silt or clay. If these are present in a layer and the clay disperses an impediment to root growth and drainage could result. This can be amended by gypsum application.

Ensuring the Success of Soil Amelioration after Ripping or Mouldboard Ploughing.

After successful physical and chemical amelioration, the soil may still undergo natural structural deterioration and hardness from coalescence even if supplied with adequate organic matter (Cockroft and Olsson; 1990). This phenomena along with slaking and dispersion (Emerson; 1969) are common where soils are deficient in organic matter particularly on sandy soils in dryland farming areas. To prolong the positive effects of soil amelioration and therefore improve soil structural condition, the following options for soil stability include:

1. Plant the site to a crop ASAP. Avoid hay.
2. Encourage roots to grow as soon as possible after ripping and possibly whilst the soils are warm, with the intent to stabilise soil aggregates using organic matter from plant root systems.
3. Harvest the crop for grain, brown manure or green manure the crop. The option of green manure fits well with growers who run a 1 year on-one year fallow rotation, particularly if there is a ryegrass problem on the site.
4. Undertake soil amelioration before the soil consolidates. Do not wait for the problem to be noticeable before it is treated. Prevention is better than cure.

Crop selection for root growth and soil stabilisation will vary depending on the type of operation. A best-case scenario for the stabilisation of soil aggregates is to use ryegrass as opposed to clover or other winter crops (Tisdall & Oades, 1979; 1980a, 1980b). Ryegrass has an extensive fine root system that has the ability to proliferate rapidly if soil conditions are favourable. There are likely to be other crops that can achieve similar results however literature is not available on the effects of other conventional crops on soil structural improvement.