Sub-soil amelioration using composts in cropping and grazing systems in Victoria

Bill Grant, Research Fellow, Future Regions Research Centre, Federation University

b.grant@federation.edu.au | **+61 407 882 070**

Subsoil amelioration using matured compost and other organic amendments can improve soil water infiltration, soil water- and nutrient-holding capacities, improve soil fertility and promote deeper plant root growth. The more stable organic fractions in matured compost will last in the soil for years, and over time deeper and stronger root growth will improve condition soils resulting in better plant access to water and nutrients down the soil profile.

What is subsoil amelioration?

Subsoil amelioration uses modified deep ripping equipment to place soil amendments down the soil profile to make soils deeper. When used appropriately on constrained soils, it has been found to increase average unirrigated crop and pasture yields in South-East Australia by 20-100% in the first few years, as well as contributing to improvements in soil characteristics that are likely to produce higher yields in following years. However, the costs of subsoil amelioration can be significant, and it is important to consider the specific surface and subsoil soil constraints are limiting yields, and how sub-soiling or other management techniques can most cost-effectively ameliorate underperforming soils.

This information sheet provides an overview of sub-soil amelioration and the factors that are likely to lead to cost-effective use of this technology.

Subsoil amelioration can help to address significant soil constraints down the soil profile and promote deeper and healthier root growth. On clay subsoils, the combination of the deep ripping 'opening up' and shattering of compacted clays and the physical, chemical and biological attributes of the soil amendments promotes deeper root growth.

Figures 1 and 2 show how amendments are placed usually at or slightly below the point where there are significant sub-soil constraints to deeper root growth. soil. This root growth helps to further amend the subsoil by adding root biomass, root exudates and promoting beneficial soil biology down the soil profile.

The action of root growth and soil biology help the soil to form more friable 'peds' (small stable aggregates) and better soil porosity. This allows better water infiltration and airflow down the soil profile, resulting in deeper and stronger root growth. Increased organic matter improves soils' ability to hold water and nutrients and make these available to plants. The organic matter also provides a stock of 'slow release' nutrient and energy feeing plants and soil biology.

Figure 1: Side view of the placement of ameliorants

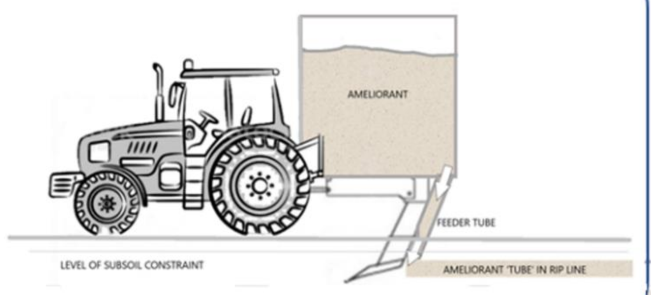


Figure 2: Cross section showing placement of ameliorants

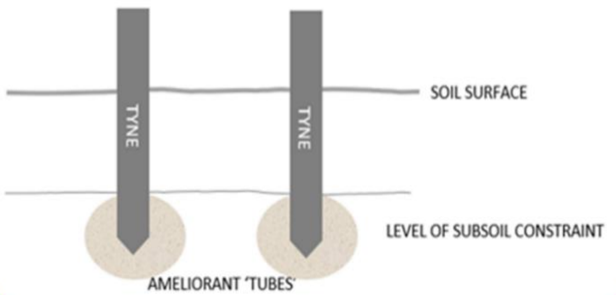
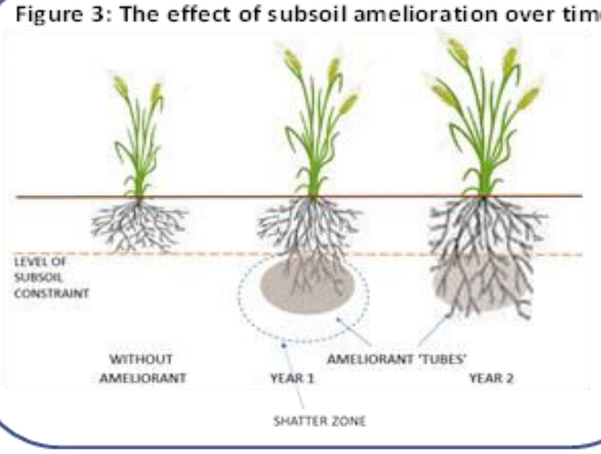


Figure 3 show how successful subsoil amelioration can improve soil over time. This shows plant roots accessing the ameliorants in the rip lines the first year and then the action of the plant roots and their associated soil microbiology colonising and improving soil between the rip lines. Over time this will result in improvement and deepening of the soil on both ripped and unripped areas in the treated area.

Figure 3: The effect of subsoil amelioration over time



Effects and benefits of subsoil amelioration

A key objective of successful soil amelioration is to create conditions where healthier plants, deeper roots and active soil biology contribute to further improvements in soil organic matter, fertility and function down the soil profile.

Subsoil amendment has four main effects on soil characteristics and plant and root growth, namely:

Physical. Ripping and soil ameliorants change the structure of the soil. The main physical effects are:

- Mechanical ripping of the soil 'opens up' the rip line and, in clay subsoils, 'shatters' neighbouring clay. This improves aeration and drainage down the soil profile and reduces the bulk density of the clay. This, along with the placement of the amendment, creates conditions favouring deeper root growth along rip lines. However, the benefits of deep ripping alone can be limited and short-lived if the subsoil has other chemical constraints or is dispersive.
- Reduced bulk density/improved porosity. The subsoiling with organic amendments places a physically less dense 'tube' of material along the rip-line. These will create a zone of 'potting mix' more favourable to root growth than the surrounding clay. Straw and nitrogen rich manures used as soil amendments are likely to breakdown more quickly and provide a less favourable root growing media for a shorter period than matured composts.
- Physical changes to soil 'ped' formation due to organic compounds contained in soil amendments and produced by plant roots and soil biology There are a range of humic compounds in soil amendments, and these, as well as exudates and bio-chemical residues from roots and soil biology, physically change soils by promoting the formation of finer and more stable 'peds' that improve soil porosity and deeper root growth.

Chemical. In Central Victoria many soils, and particular sub-soils, have significant chemical constraints associated with pH, nutrient deficiency and availability, sodicity, toxicity, poor nutrient- and water-holding capacities, and poor plant-available water characteristics. It is important to assess and test soils to depths of at least 40-60cm to identify whether sub-soils have significant chemical constraints and consider how subsoiling can be used to address these. Subsoil amelioration provides an opportunity to place chemical as well as organic amendments down the soil profile. Soil amendments such as lime and gypsum are not very soluble, so surface application is often slow to percolate down the soil profile to amend constrained subsoil. There is also opportunity to add nitrogen, phosphorous and trace element fertilisers down profiles to promote deeper root growth. In the years immediately following application, the nitrogen benefit of soil amendments can be important to promote deeper root growth and the benefits such root growth has on amending sub-soils. The nitrogen content of amendments has been found to be a significant factor in yield increases in the first year or two following amelioration. Testing soils for chemical constraints is vital when planning which amendments to use and crop and pasture management in the years following amelioration.

Key messages:

- Subsoil amelioration promotes deeper and stronger root growth on soils with compacted and chemically constrained sub-soils.
- Ameliorants treat the soil and extend the effects of deep ripping.
- Matured compost lasts longer in soil than other ameliorants, meaning farmers get more years out of ripping and amelioration.
- Compost contains organic compounds that improve soil structure, water holding characteristics and nutrient availability.
- Compost can be blended with lime, gypsum, fertilisers, biochar or minerals to optimise benefits.

Biological. The addition of organic matter and nutrients to soils promotes soil biology and root growth. Some amendments may contain beneficial microbes and organic compounds that also promote soil health and root growth, but the main biological benefit of the organic amendments appears to be their ability to 'feed' soil biology and plants. The organic amendments help to build soil organic matter and improve soil characteristics and the resulting healthier plant and root growth feeds beneficial soil ecosystems.

Soil-water characteristics. Improving soils' water infiltration and drainage and their capacity to hold water helps to maintain living plants and roots during dry periods. Maintaining living plants protects soils and beneficial soil biology and helps to build and maintain beneficial levels of soil organic matter and maintain pasture diversity. It also means that pastures are ready to rapidly respond when seasonal rain breaks arrive. Improving drainage on heavier clay soils reduces the risks of waterlogging during wet periods and allows deeper root growth.

Assessing soils

It is vitally important to address surface and subsoil constrains through a combination of field assessment of soil characteristics, as well as laboratory testing of soil samples. A useful guide is the NCCMA Soils Guide 2023

The knowledge gained from soil assessments and testing can help to determine whether subsoiling is likely to be cost-effective and the ways in which its positive effects can be optimised and made to last for years. In central Victoria, subsoiling is mainly effective on soils with shallow topsoils overlying heavy and non-porous clays and/or subsoils with overly acidic or alkaline conditions that limit deeper root growth.

Use of organic and other amendments

A range of amendments can be used to ameliorate subsoils. Advantages and disadvantages of these are summarised in Table 1. Composted amendments have advantages over mineral ameliorants and can be blended with these and fertilisers to maximise the effectiveness of subsoiling. A great advantage of composted organic amendments is that they will last for longer in the soil and provide a 'potting mix'-like growing media for plant roots for years.

Table 1: Characteristics of soil amendments

Type of amendment	Benefits	Possible limitations/disadvantages
Matured compost	• Physical, chemical and biological soil conditioning (see previous discussion) resulting in improved soil porosity, water- and nutrient-holding capacity, biological nutrient cycling and deeper and stronger plants roots. • Slow release of a range of plant nutrients. • Stable organic matter will persist in the subsoil for several years, allowing plant roots to access deeper nutrients and water and colonise soil between rip lines. • Composts can be blended with fertilisers, gypsum and lime to increase the effectiveness of all products. • Soluble humic substances migrate through soil having wider effect on surrounding soil.	• Compost can have higher per tonne costs than some other amendments, but are usually cost-competitive because they last for longer in soil and have a wider range of benefits. • Specialised application equipment is needed to ensure products flow well into rip lines. This is also true of other amendments. Dry fine compost generally flows well in such equipment.
Gypsum	• Chemical modification of sodic and soils with low exchangeable calcium relative to sodium and magnesium. • Provides sulphur for plant nutrition.	• Gypsum is a mined product and supply is finite and becoming more limited in Victoria, resulting in higher product and transport costs. Some recycled products made from waste drywall 'plaster' • Wet and 'lumpy' products do not always flow well in subsoiling equipment. • Products are not very soluble, so do not migrate well through soil and need high soil moisture to have effect.
Lime	• Chemical modification of acidic pH, and will also contribute some calcium to address sodic and magnesium imbalances. • Lime is generally a low-cost amendment.	• Lime is a mined product and results in significant fossil carbon greenhouse gas emissions in production and as it breaks down in soil. • Wet and 'lumpy' products do not always flow well in subsoiling equipment.
Immature compost	• Will provide organic matter, some humic substances and nutrients to the soil.	• Can 'draw down' nitrogen and phosphorous for a period after application. • Can have negative 'phytotoxic' impacts for a period after application. • Less of the organic matter will persist in the soil for more than a few years.
Poultry shed litter	• Will provide organic matter, some humic substances and nutrients to the soil. • Generally, poultry shed manure contains higher N than matured compost.	• The high nitrogen to carbon ratio will typically result in greater losses of both from the soil, resulting in less of the ameliorant remaining in the soil. • Wet and 'lumpy' products do not always flow well in subsoiling equipment and can create odour issues for operators.
Cereal and legume straw	• Will provide organic matter and nutrients to the soil. • Straw can help aggregate formation on clay soils. • Other amendments can be added. • Legume straw generally contains higher N than cereal straw. • Cereal straws have higher lignin and silica levels and may last longer in soil.	• Although the straw is 'free' on farm, it can have high costs to convert it to chaff or pelletised for use as an ameliorant. • The high nitrogen to carbon ratio will typically result in greater losses of legume straw from the soil, resulting in less of the ameliorant remaining in the soil.
Biochar	• Improves soil water- and nutrient-holding capacity. • Will persist in the soil for centuries • May stimulate and promote root growth and beneficial soil biology.	• Often has high costs, but it will persist in the soil 'forever'. • Biochar is inert and insoluble, so will not migrate in the soil profile. • Biochar can bind strongly to nutrients and not make them available to plants without biological activity.

Examples of products in use

The following figures show how sub-soil amelioration increases root growth and depth on soils with an impermeable and compacted clay subsoil.

Figures 4 and 5 show composted soil amendments being applied. These shows the modified ripping equipment and compost flowing down rip lines.

Figure 4: Subsoiling unit

Figure 5: Compost flowing down rip lines

Figure 6 shows composted amendments in the soil profile immediately and two years after being applied. This shows the dark compost placed in a compacted subsoil. This shows two years after application amendment is still clearly visible and the strong root growth in the a 'potting mix' like-amendment compared to the neighbouring clay.

Field observations have found that four years after the amendment has been applied, the rip lines still contain visible compost, and soils are around 20cm deeper in along rip lines compared to areas half-way between rip lines. The soil amendments 'tubes' have also been observed to contain more plant available water over dry summer months than upper soils and surrounding clays.

Figure 6: Composted soil ameliorant immediately after application (left) and two years later (right)

Conclusions

Composted soil ameliorants can improve soils with compacted and sodic subsoils. They provide a less dense soil for deeper plant roots to grow into, and have physical, chemical and biological attributes to re-condition sub-soils. They improve soil water- and nutrient-holding characteristics and provide slow- release nutrients. They also promote nutrient and carbon cycling by beneficial soil biology which improve nutrient availability to plants.

References and further reading

Armstrong, et al 2017 Can subsoil amelioration improve the productivity of grain production in medium to high rainfall environments?

Armstrong etc al 2021 Subsoil amelioration - update on current research, GRDC

Tavalkkoli et al Understanding the amelioration processes of the subsoil application of amendments

Sale P, Tavakkoli E, Armstrong R, Wilhelm N, Tang C, Desbiolles J, Malcolm B, O'Leary G, Dean G, Davenport D, Henty S and Hart M (2021). Ameliorating Dense Clay Subsoils to Increase the Yield of Rain-fed Crops. *Advances in Agronomy*, Volume 165

This information sheet has been developed as part of a research and demonstration site being conducted by Federation University's Future Regions Research Centre with the support of Sustainability Victoria's *Circular Economy Research and Development Fund*; and Elmore Compost and Organics. For further information please contact Bill Grant via b.grant@federation.edu.au or 0407 882 070