Plant / soil interactions

The soil environment can have a profound effect on pasture growth. The soil stores, transfers and, in some cases, transforms the water and nutrients needed for plant growth. The capacity of the soil to provide these growth resources in an available form, and the ability of plants to access them, are the key factors to consider.

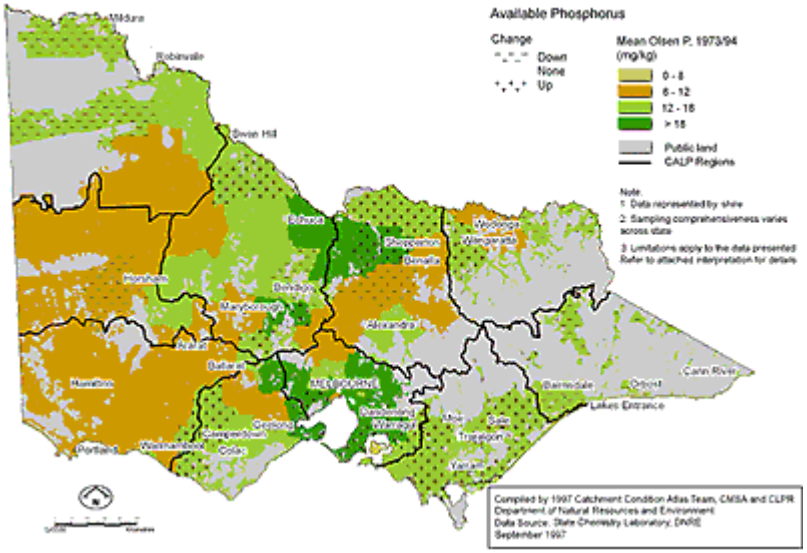
In addition, there are distinct soil conditions such as acidity or salinity which can directly affect plant growth. Some plants have adaptive features which allow them to cope with these conditions better than others, in exactly the same way as some plants are better adapted to low soil moisture availability, or high temperatures, than others.

A typical Victorian soil profile, showing a relatively shallow topsoil overlying a poorly-drained B horizon.

Information about the soil environment for plant growth can be gleaned from the taxonomic description of soil types and supporting data on soil chemical properties. This information can be used to produce maps of the suitability of soils for plant production. However, these are a very general description of the soil environment. In practice, the spatial distribution of soil types is much greater than indicated by these maps. They would have limited value when assessing soil limitations at the farm level. We cover this topic in the tutorial "A Question of Scale". Nevertheless, the maps provide a conceptual framework to help us understand the occurrence and distribution of soil limitations.

There are four soil limitations to consider in relation to pasture growth and choice of species: nutrient availability, acidity, salinity, and soil physical properties. Nutrient availability in the soil environment depends on characteristics of the soil itself (eg. parent materials, and degree of weathering), plus additions of nutrients in fertiliser. Most of the soils used for pasture production in Australia are infertile in their natural state, and several macro-nutrients and, in some cases, micro-nutrients must be supplied to support good pasture growth. Reliance on legumes to supply the nitrogen for grass growth in pasture mixtures (see the tutorial "Principles of a Mixture") means most farm fertiliser programs are targeted to overcoming

nutrient deficiencies for legume growth (mainly P, K and in some cases Mo). This in turn overcomes the principal nutrient deficiency limiting growth - nitrogen.



Map of mean soil Olsen P levels in Victoria over the period 1973 – 1994. Optimal Olsen P levels are considered to be around 14 for sheep / beef pastures and 25 – 30 for dairy pastures. Source: Victorian Resources On-Line

Most of the improved pasture species, such as tall fescue, that are used in Victoria require moderate high levels of soil fertility (Olsen P levels > 12) to grow at or near their maximum.

Tall fescue (*Festuca arundinaceae*) is an example of an 'improved' pasture grass that performs best at moderate to high levels of soil fertility.

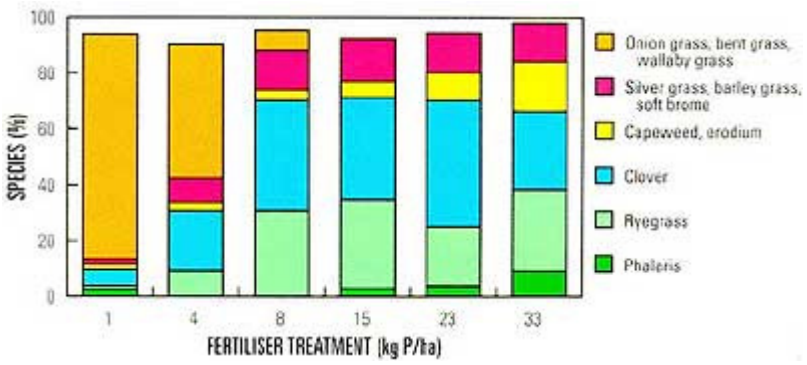
Other species are better adapted to low soil fertility. These species have usually originated from infertile habitats, and have adaptive features such as low relative growth rates, slow tissue turnover, and a capacity to store nutrients for later use. These features reduce their demand for nutrients from the soil environment and so allow them to tolerate nutrient deficiencies. Many of the common pasture weed species display these characteristics.

Some of these low-fertility tolerant species can also pre-empt nutrients through features such as high root:shoot ratios, and a physiological capacity to extract nutrients from the soil solution at nutrient concentrations below those at which other species can operate. These features allow them to out-compete others species when nutrients are limiting. A good example of this is bent grass (*Agrostis castellana*) which can completely dominate pastures in medium and high rainfall zones if soil fertility is low and pastures are poorly utilised.

Bent grass (*Agrostis spp.*) is well-adapted to infertile soils and can dominate pastures, as shown in this photo.

By contrast, the productive, improved pasture species have mostly originated from fertile habitats and have high relative growth rates, high rates of tissue turnover and minimal nutrient storage. They are more suited to, and competitive in, environments where nutrients do not significantly limit growth.

This is the basis for the so-called high input pasture production systems, which create a soil environment that favours the productive species over the weeds by using relatively high inputs of fertiliser. The result is a more-productive pasture, where the species present are better able to exploit the available rainfall for growth, in turn leading to greater carrying capacity of the pasture.



Differences in pasture composition under different fertiliser treatments in the Long Term Phosphate Experiment at PVI Hamilton. Note the dominance of the weed grasses onion grass and bent grass at the two lowest fertiliser rates, and the increased presence of clover and ryegrass at the higher rates, reflecting the relative nutrient requirements of the species. Source: Agriculture Victoria, 1999

Like low nutrient availability, the limitation imposed by **soil acidity** can be overcome by management practices, particularly the use of lime. But this may not always be cost-effective, especially when the soil is moderately - strongly acid and requires a lot of lime to raise the pH to a level that allows good plant growth. Also, lime application will not address the problem of acid subsoils.

As with most limiting factors, there is variation within and between species in tolerance of soil acidity. Some sub clover cultivars are tolerant of moderate acidity but sub clover dominance, and the associated accumulation of H^+ ions when excess nitrate is leached from the soil, is an important ***cause*** of acidity.

Perennial grasses play a useful role in managing acid soil problems by preventing the leaching of nitrates from under clover dominant pastures. Among the perennial grasses, cocksfoot is generally more tolerant of acidity and the commonly associated problem of high soil aluminium levels than, for example, phalaris. Lucerne requires soil pH levels of greater than 6, while the medic species perform and persist best in alkaline soils.

Acidity tolerance levels for different pasture species

	Soil pH (water)		**Soil pH (CaCl2)**	
Plant species	Min	Max	Min	Max
White clover	5.3	6.5	4.5	6.5
Sub-clover	5.3	7	4.5	6.5
Perennial ryegrass	5	6.5	4.3	6.5
Annual ryegrass	5	6.5	4.3	6.5
Phalaris	6	8	5	6.5
Cocksfoot	5	7.5	4.2	6.5
Lucerne	6	7.5	5.3	7

Exchangeable aluminium tolerance levels for different pasture species

	0.01 M CaCl2		**1.0 M KCl**	
Plant species	Min	Max	Min	Max
White clover	0	15	0	120
Sub-clover	0	15	0	120
Perennial ryegrass	0	15	0	150
Annual ryegrass	0	15	0	150
Phalaris	0	8	0	80
Cocksfoot	0	15	0	150
Lucerne	0	5	0	40

Source: Cameron, G.

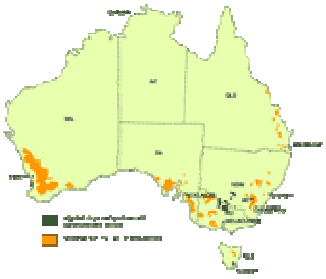
Areas affected by soil acidification

Soil salinity occurs widely throughout Australia, and may impair pasture growth when the saturated electrical conductivity (EC) is greater than about 4 dS /m. Pasture species vary in their tolerance of salt. Clovers, particularly white clover, are more sensitive than the grasses. The reduction of pasture production in salt-affected soils is often due initially to the decline in legume growth which can occur at EC's of around 1.5 dS / m.

The use of deep-rooted perennial grasses or lucerne is an important control strategy for dryland salinity because of their ability to dry down the soil profile to a greater extent than annual pastures, and therefore help control groundwater table levels. In areas already affected by salt, tolerant species like strawberry clover and tall wheat grass can be used to maintain ground cover and some production.

Salinity tolerance levels for different pasture species.		
	Electrical conductivity (EC se (sat extract)	
Plant species	Minimum	Maximum
White clover	0	2.6
Sub-clover	0	2.6
Perennial ryegrass	0	4
Annual ryegrass	0	4
Phalaris	0	4.2
Cocksfoot	0	4
Lucerne	0	4

Source: Cameron, G .



Areas affected by soil salinity

Soil physical properties such as texture and bulk density may also affect the environment for plant growth. They have a large influence on the ability of a soil to store water, as well as the rate at which excess water drains from the root zone. Heavy clay soil texture can mean soils become waterlogged during wet seasons, and waterlogging can directly impair plant growth. A good supply of oxygen in the soil is important for the respiration of microbes and plant roots. When soils are saturated, the supply of oxygen is reduced since oxygen diffuses faster (by a factor of 10^4) through air than through water. Plant root activity can be affected under these conditions, leading to reductions in pasture growth.

Again, there are plants that can tolerate the effects of waterlogging better than others, notably members of the subterranean clover subspecies *yanninicum* such as the cultivars Larisa and Trikkala. These are good options for situations where soil physical properties combine with rainfall patterns to give rise to periodic waterlogging.

Soils like this with a relatively shallow watertable can become readily waterlogged during winter and early spring in southern Australia.

Summary

- Soil factors have a strong effect on pasture growth, and the selection of species and cultivars for pasture mixtures must consider the adaptability of plant material to any soil limitations that may be present.
- The main soil factors to consider are: nutrient availability, acidity, salinity, and soil physical properties such as texture and bulk density. The first two of these can often be modified by fertiliser management and liming, respectively. However, salt accumulation and poor soil structure are not easily modified, and so species must be chosen carefully if there is a risk that these factors might limit plant growth.
- Regional soil maps are useful for gaining a general overview of soil types and the associated soil environment for plant growth, but there is enormous spatial variability in soil types within regions, within farms, and even within paddocks. Soil properties must be assessed at the paddock level when considering pasture mixtures for a property.