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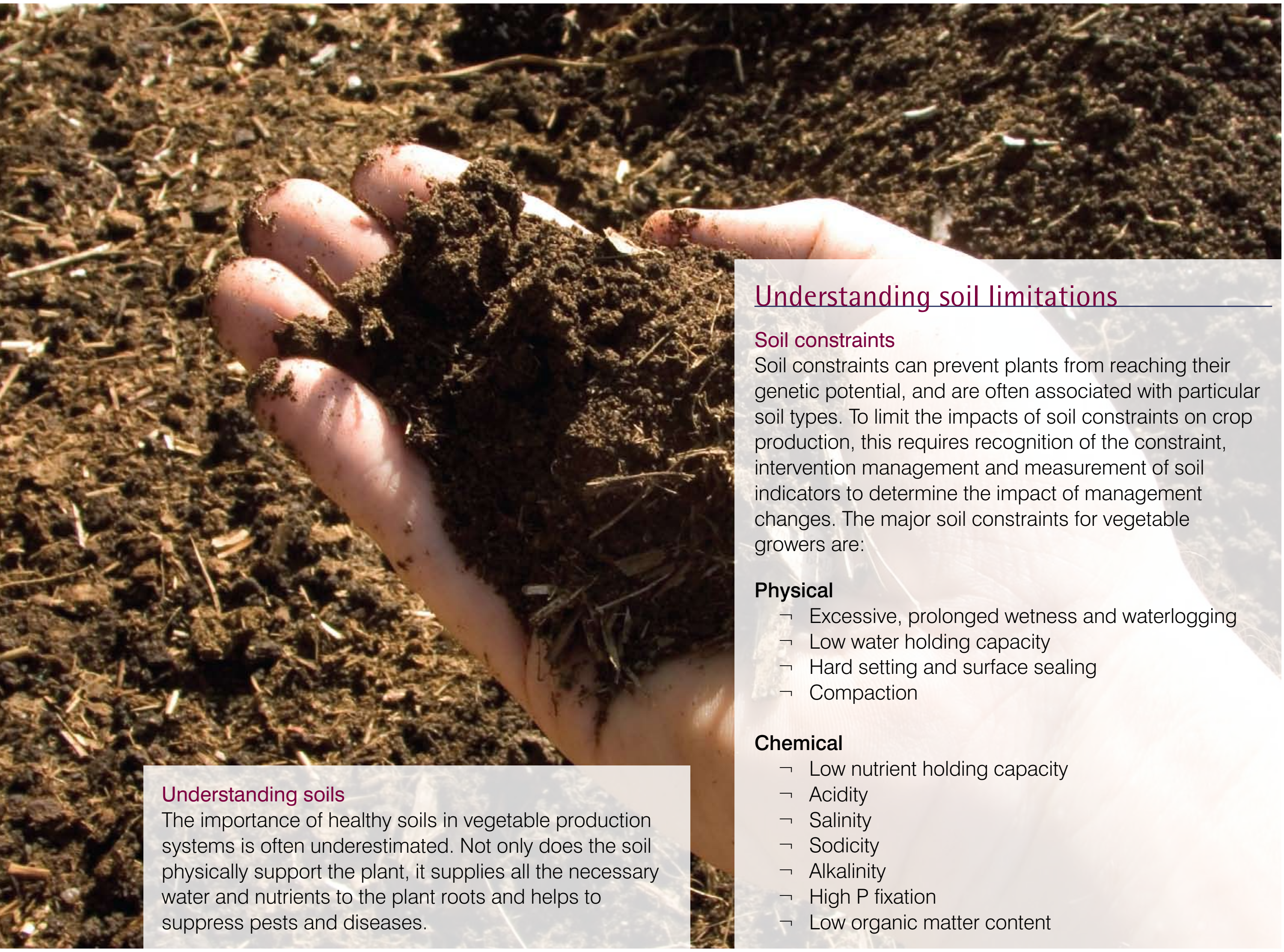
Indicators of Soil Health

Healthy soils can mean more than just an absence of pests and diseases. In vegetable production, healthy soils can mean the difference between an average and an excellent crop. Soil is a complex ecosystem that depends on the interaction of physical, chemical and biological properties. By looking after the health of your soil, you can contribute to the overall health of your crop.

The bottom line

- Understanding soil is an important element in maintaining soil health. There are many factors involved with maintaining high-quality soil, these factors involve soil constraints, soil types, soil nutrients and general soil health management.
- It is essential that growers understand and know what soil type and limitations their crop contains. This can be done effectively through four soil measurement techniques, each looks at soil texture, soil pH, dispersion and colour.
- An important element in soil is measuring its function, which determines behaviour, nutrient holding capacity and soil's organic carbon. A series of indicators will assist growers with determining changes in soil properties and changes in soil function.



Understanding soils

The importance of healthy soils in vegetable production systems is often underestimated. Not only does the soil physically support the plant, it supplies all the necessary water and nutrients to the plant roots and helps to suppress pests and diseases.

However, natural processes occur within the soil to stabilise, balance and support a vibrant ecosystem. These soil ecosystem functions include suppressing crop pests and diseases by supporting a large number of different organism species, recycling nutrients from organic matter and crop residues, whilst keeping soil stable to help water and air move around the roots of plants. If the ecosystem of agricultural soil is healthy, crops are able to withstand negative impacts, like soil borne diseases and hot dry weather.

Measuring soil function

Soils have inherent properties that are associated with soil types, which determine the soil's behaviour, such as the texture or nutrient holding capacity of the soil. Soils also have dynamic properties, such as the level of organic carbon in the soil, which are influenced by management practices. This makes the dynamic soil properties useful measures of the effectiveness of particular farming techniques.

A range of indicators have been developed to measure changes in soil properties and assess changes in soil function. Some functions will respond quickly to practice change, while others may take a long time to respond.

Understanding soil limitations

Soil constraints

Soil constraints can prevent plants from reaching their genetic potential, and are often associated with particular soil types. To limit the impacts of soil constraints on crop production, this requires recognition of the constraint, intervention management and measurement of soil indicators to determine the impact of management changes. The major soil constraints for vegetable growers are:

Physical

- Excessive, prolonged wetness and waterlogging
- Low water holding capacity
- Hard setting and surface sealing
- Compaction

Chemical

- Low nutrient holding capacity
- Acidity
- Salinity
- Sodicity
- Alkalinity
- High P fixation
- Low organic matter content

Biological

- Soil borne diseases
- Soil insect pests

Soil types

Four simple soil measurements can be used to determine soil type and determine the inbuilt limitations of the soil: soil texture, soil pH, dispersion and colour.

Soil texture refers to the proportion of sand, silt and clay in soil and descriptions reflect the major proportions of each component. Sandy soils tend to be limited by low water and nutrient holding capacity, low soil organic carbon and have the potential to become acidic. Loam soils, with roughly equal proportions of sand, silt and clay can become hard setting, form crusts on the soil surface and are prone to compaction.

Soil pH refers to the concentration of hydrogen ions ($H+$) in the soil solution, which in turn represents the acidity or alkalinity of the soil. As soil becomes more acidic the availability of calcium, magnesium and potassium decreases, while aluminium and manganese increases and may become toxic. As soils become more alkaline – zinc, iron and manganese become less available to plants.

Dispersion and slaking refers to the stability of soil particles in water. Dispersion occurs when clay particles are released into water, usually due to a high proportion of sodium in the soil, causing the water to become cloudy. Slaking is when the soil aggregates in water fall apart. This indicates that the forces holding the aggregate together are weak. Evidence of dispersion and slaking indicates soil is susceptible to compaction, surface sealing, waterlogging and may also be low in organic matter.

Soil colour is influenced by a number of factors, including minerals in the soil, weathering, aeration and organic matter. Black soils tend to have relatively high organic matter, but are susceptible to waterlogging and compaction. White soils have low organic matter and typically have poor water and nutrient holding that can fix phosphorus, tying it up and making it unavailable to plants.

Researchers at the Department of Primary Industries (DPI) in Queensland and New South Wales have developed a series of soil health indicators. These indicators measure soil functions and provide an overall assessment of the health of the soil being tested.

Indicators found in nurtrient tests

Soil organic carbon

Soil organic carbon is usually less than 5 per cent of the total soil, but has the greatest influence on soil properties. Soil organic carbon is related to nutrient recycling, nutrient holding capacity, water storage, structural stability of the soil, diversity of organisms living in the soil and inactivation of toxins.

Increasing organic soil carbon, reduces soil bulk density, increases soil aggregation and stability, reduces soil penetration and increases the amount of water available to the plant. Increasing organic carbon can also increase nutrient storage and release, and can buffer changes to pH.

Nitrate

Soil nitrate (NO_3^-) is a form of nitrogen available to plants. The atmosphere is made up of 78 per cent nitrogen; however it is unavailable to plants and needs to be converted to nitrate or ammonia before being absorbed by plant roots.

Some micro-organisms associated with legume crops are able to convert atmospheric nitrogen into soil nitrate. However, most nitrogen is added as fertiliser. It is important to balance fertiliser applications to ensure that sufficient nitrogen is present for crop production but also to avoid excessive levels that can leach from the soil or cause an imbalance in soil organisms.

Phosphorous

Phosphorus is important during early plant growth. Most phosphorus is attached to soil particles and does not readily move with soil water. Soils high in iron (Fe) are able to fix phosphorus to their particles, making them unavailable for plant growth. The amount of phosphorus fixed to soil particles is measured by the phosphorus buffering index (PBI).

A root fungi called Mycorrhiza helps the plant extract phosphorus from the soil, and protects the plant from pathogens. If phosphorus levels are too high, the fungi doesn't establish in the plant's roots, leaving plants susceptible to attack from soil borne diseases.

Soils that have high phosphorus fixation should have phosphorus applied in a band rather than broadcast over the soil surface.

Cation Exchange Capacity (CEC)

CEC is the soil's ability to hold nutrients through electrostatic forces. It is often a reflection of soil fertility, and is influenced by the amount of clay and organic matter in the soil. Major cations are calcium, potassium, sodium and magnesium which are held by negative charges in the soil. Soils with low CEC can lose nutrients easily through the movement of soil water.

Sodium saturation

Sodium saturation measures the amount of sodium (Na) as a percentage of the cation exchange capacity (CEC). Soils with a high proportion of exchangeable sodium are referred to as sodic soils. Sodicity is different to salinity, although they may both occur together. Sodic soils tend to lose aggregation and disperse, prevent water infiltration, develop surface crusts and have poor aeration, creating poor conditions for plant growth. The addition of gypsum is required to correct the dispersion that occurs in sodic soils.

Indicators requiring additional measurements

Bulk density

Bulk density is used to determine the compaction of soil by calculating the ratio of the mass of the soil in a given volume. The lower the mass, the less dense the soil and the more pore spaces available for water, air and root movement. Bulk density tends to be higher in sandy soils, due to the larger particle sizes. If the soil has high bulk density, then porosity is low and the roots need to work harder to take up water and nutrients.

Aggregate stability

Soil aggregates are formed when soil particles come together and the stability of the aggregates are influenced by the level of organic matter and proportion of sodium (sodicity) in the soil.

Aggregate formations favour water infiltration, soil aeration, nutrient recycling and root development. Soils with poor aggregate stability tend to have surface crusting and compaction, increasing both runoff and erosion.

Soil resistance (measured by soil penetrometer)

Soil resistance may be an indication of sub-soil compaction or surface crusting, leading to restriction of plant and root growth. Resistance is measured using a device called a penetrometer, and measures the ease with which an object can be driven into the soil. A higher penetrometer reading indicates more energy required for tillage implements and plant roots to move through the soil.

Soil health management

Tillage can pulverise soil, shattering the particles in dry soil or smear wet soil, leading to compaction and poor aggregate stability. The selection of tillage implements and when to work the soil, need to be carefully managed to promote good soil health.

Green manures and cover crops are grown to improve the soil and therefore are not harvested or sold. They are usually ploughed back into the soil and the nutrients recycled for the next crop.

Crop rotation is an important component of soil and pest management. By rotating crops with different types of root systems, such as rotating crops with tap roots and fibrous roots, soil structure can be enhanced. Crop rotation may be as simple as switching crops in alternate years to a complex rotation that involves numerous crops over several years.

Organic amendments may include manures, composts, municipal and industrial wastes. Usually simple organic compounds have been decomposed and the humic material remains. The qualities of amendments will depend on the type of amendment, what it is composed of and the amount applied to the soil. Organic amendments usually require follow up applications to stabilise properties.

Further reading

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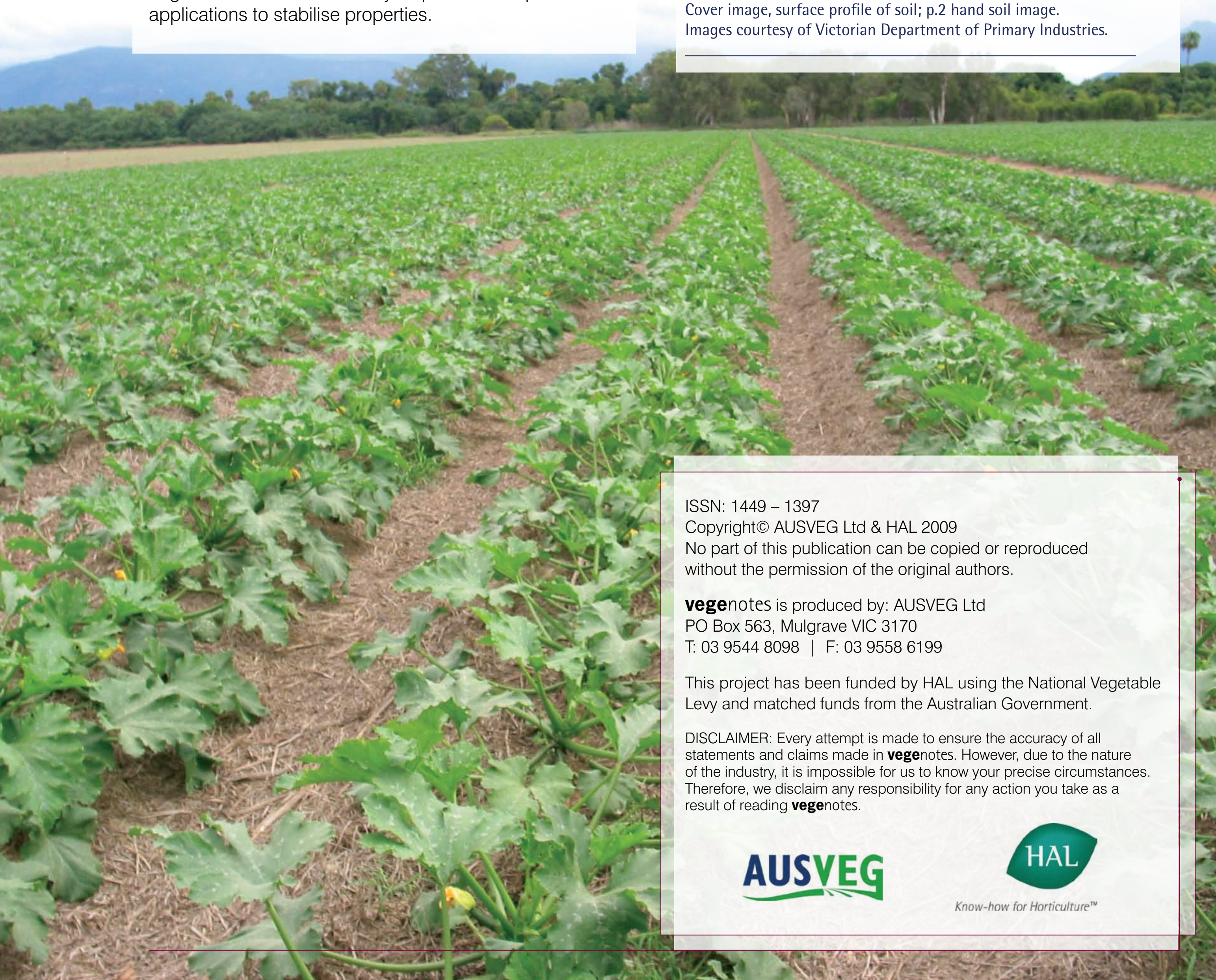
Image: Crops with good soil health.
Cover image, surface profile of soil; p.2 hand soil image.
Images courtesy of Victorian Department of Primary Industries.



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