

Strategic Analysis Paper

31st May 2016

Soil Nutrient Management

Christopher Johns

Research Manager

Northern Australia and Land Care

Key Points

- The most basic components of soil are minerals, organic matter, water and air.
- Mineral nutrients, by definition, are critical to health, vigour and productivity of plants, particularly in agriculture.
- Soil organic matter (SOM) not only stores nutrients in the soil but also is a direct source of nutrients. Its presence is considered an important indicator of fertile soil.
- Soil fertility is greatly influenced by five broad factors: parent material, climate, biota, time and topography.
- Two properties that have a profound impact on the soil's water holding capacity, nutrient retention, nutrient supply and drainage are soil structure and soil texture.
- Soil texture describes the ratio of clay, loam and sand in a specific soil.

Summary

The importance of appropriate plant nutrient management in agricultural soil cannot be overstated. If agricultural and pastoral activity is to be maximised in a sustainable fashion, it is imperative that plants are supplied by proper nutrition. The available quantity of many of these essential plant nutrients is finite and, once depleted or degraded, cannot be easily restored. In addition to the presence of nutrients in the soil, fertility is also influenced by the structure of the soil and the activity of a vast and diverse range of soil microbes. This management process requires an understanding of the function and interaction of all soil components which can be highly complex and, at times, highly variable or even volatile.

Analysis

Soil Composition

An important element in this understanding is soil composition. The basic components of soil are minerals, organic matter, water and air; soil minerals and organic matter hold and store nutrients, soil water moves nutrients to plants and air plays an integral role since many of the microorganisms need air to undergo the biological processes that release nutrients into the soil.



Figure 1 Soil preparation for horticulture. Source" Arno KleineSchaars, Flickr.

Minerals and organic matter are generally stable although, if not managed properly, may soon be depleted from the soil. The water and air components, however, are more dynamic and constantly change as the soil becomes wet or dry.

Soil minerals play a vital role in soil fertility since their surfaces are potential sites for nutrient storage. Different types of minerals hold and retain different amounts of nutrients. Minerals vary greatly in size and composition from large rocks or boulders to particles that are invisible to the eye. Particles, in turn, are divided into two groups: the coarse fraction and the fine earth fraction. The latter includes sand, silt and clay.

Weathering is the process that results in these smaller and finer particles that we call soil. Weathering also influences the availability of plant nutrients. There are two types of weathering: physical and chemical.

Physical weathering is caused by the wetting and drying of rocks, erosion and by the action of animals and plants.

Chemical weathering is caused by rain water reacting with mineral grains of rocks to form new minerals (clays) and soluble salts. This is important for nutrient management since the resulting soil particles retain and supply nutrients.

Soil Organic Matter (SOM)

SOM not only stores nutrients in the soil but is also a direct source of nutrients. Indeed, some of the world's most fertile soils contain high amounts of organic matter.

Most SOM accumulates within the surface layer of soil. It may be clustered into two groups: one includes all undecomposed organic material such as twigs, roots and living organisms while the other includes humic acids, fulvic acids and humin. The latter is a dark material that is highly resistant to decomposition.

Without additions of organic matter, tillage practices will greatly reduce organic matter. Therefore, no-till or minimum tillage with the return of organic matter to soil are increasingly seen as improving and conserving soil quality.

SOM includes the following:

- All carbon containing substances.
- Living organisms (soil biomass).
- The remains of microorganisms that once inhabited the soil.
- The remains of plants and animals.

Organic compounds that have decomposed within the soil and, over thousands of years, are reduced to complex and relatively stable substances called humus. The importance of humus or humic substances, notwithstanding,

It is important to maintain SOM by adding fresh amounts of animal and plant residues as it performs many functions.

Surface soils contain between 1 and 6 per cent organic matter. SOM performs a number of important functions:

- It acts as a binding agent for mineral particles. This results in easily crumbled surface soils.
- It increased the amount of water that soils can hold.
- It provides food for soil organisms.

Humus, an integral part of organic matter, which is fairly stable and resistant to further decomposition, is also an important source of plant nutrients.

Water

Soil water also has important functions:

- It is essential for the life of plants and organisms in the soil.
- It provides a pool of dissolved nutrients that are readily available for plant uptake.
- It is necessary to weather soil.

The water holding capacity of soils depends on the size of the soil's particles and spores. Sandy soils, for instance, have large particles and spores. Large spores, however, do not have a great ability to hold water. Sandy soils, therefore, drain excessively. On the other hand, clayey soils with small particles and spores have a greater water holding capacity.

Air

The approximate composition of air is 78% nitrogen, 21% oxygen and 1% other gasses including carbon dioxide. Soil air is needed by many microorganisms that release plant nutrients to the soil. The appropriate balance between air and water is also important. Too much water, for instance, reduces the amount of oxygen in the soil, limiting the organisms that can survive in it. Maintaining the right balance, therefore, is critical to crop management.

Soil Profile

A valuable insight into soil fertility can be achieved by examining the soil profile. Due to weathering and the decomposition of organic matter, profiles can be intricate and diverse. The depth of soil differs greatly in different regions. The rich soils of the northern hemisphere can be metres deep, while in parts of Australian ancient soils only extend to a depth of a few millimetres. By using common technology, however, farmers, scientists and hydrologists can make judgements about how a soil might be used and how it might react to a particular use.

A soil profile is made up of distinct layers known as horizons. A horizon runs roughly parallel to the soil surface and has different properties and characteristics from the layers above and below. These may range from a surface horizon that comprises organic matter at various stages of decomposition to a sub-surface horizon in which soluble nutrients have been lost from the soil due to precipitation or irrigation. The deepest horizon may be the least weathered.

Soil Fertility

Soil fertility is greatly influenced by the factors of soil formation. Broadly speaking five factors influence this process;

- Parent material,
- Climate,
- Biota,
- Time, and
- Topography.

Parent Material

Parent material may be mineral rock and/or organic matter. When exposed to the atmosphere or deposited on the earth's surface, soil formation begins. The type of parent material and how it is formed will greatly influence the properties of soil. For instance, finely textured parent materials tend to weather into finely textured soils while coarsely weathered textured parent materials weather into coarsely textured soils.

Climate

The effects of climate on soil formation cannot be underestimated. Together with weathering, for instance, high levels of precipitation and temperature can remove or leach nutrients from the soil and thus reduce fertility.

Temperature also has a profound effect. For instance, warm temperatures, coupled with high moisture, will increase the weathering process.

Biota

Biota is the vegetation, animal and soil microorganisms that cover and inhabit the soil. Current evidence shows that soil biota constitute an important living community in the soil system, providing a wide range of essential services for the sustainable functioning of soil and all land ecosystems. Soil organisms (e.g. bacteria, fungi, protozoa, insects, worms, other invertebrates and mammals) shape many critical soil functions including the regulation of nutrient cycles. Populations of soil organisms, particularly microbes, are strongly influenced by a range of environmental factors, for instance, soils that develop in grasslands will be significantly different from soils that develop in forests.

Time

With time, soils undergo many changes. Microorganisms, such as bacteria and fungi, form soils through the decomposition of organic matter and the binding of soil particles. Earthworms create channels as well as secrete substances that bind soil particles together. Animals, directly or indirectly, transform soil through many activities.

Topography

Topography, the final factor, relates to the lay of the land. It describes the steepness or flatness of a plane, depressions and elevations, drainage patterns and orientation of the land and hence, the soil it contains.

Soil Texture and Soil Structure

Two properties that have a profound impact on the soil and affect its water holding capacity, nutrient retention, supply and drainage are soil texture and soil structure.

Soil texture is defined by its relevant properties of sand, silt and clay. Sand has the coarsest texture while clay had the finest. A soil that exhibits a relatively even proportion of all three is called loam.

Soil structure is the arrangement of soil particles into groups, commonly called aggregates. Generally, only very small particles form aggregates. Soil aggregation can result from a number of actions:

- Microorganisms excrete substances that act as cementing agents that bind soil particles together.
- Fungi have filaments called hyphae, which extend into the soil and tie particles together.
- Roots also excrete sugars that help bind minerals.
- Soil particles may also be attracted through electrostatic forces, the attraction or repulsion of soil particles that occurs when those particles are electrically charged.
- Soil mineralogy can also cause great differences in soil fertility. Knowledge of mineralogy, therefore, helps to determine an appropriate management strategy for a particular soil. For instance, less weathered soils, under certain conditions, are said to have a “cation exchange capacity” or CTC. This is the soil’s ability to attract, retain and supply nutrients such as calcium, potassium, ammonium and magnesium. The surfaces of less weathered clay minerals generally have a negative charge. Such surfaces attract positively charged ions.

Nutritional Management

Turning now to the issue of nutritional management, a definition that attracts attention is that a sound nutritional management plan is “to ensure the availability of adequate nutrients for crop production with minimal nutrition loss in runoff or leaching from the root zone.”

A nutrient is considered essential if a plant cannot complete its life cycle without it. There are twelve essential nutrients. In addition, plants require hydrogen, oxygen and carbon.

A vital consideration is the movement of the nutrient from soil to root. There are three basic methods:

- Root interception occurs when a nutrient comes into physical contact with the root surface.
- Mass flow happens when nutrients are moved to roots by the movement of water
- Diffusion involves the movement of nutrients along a “concentration gradient”. In the same way that sugar dissolves in water, the nutrient moves through water until it is evenly dissolved.

Once water and nutrients enter the root system, they are then available to other parts of the plant such as structural tissue, leaves and reproductive systems. Some nutrients are able to move more readily within the plant tissue than others. In general, when certain nutrients are

deficient in plant tissue, that nutrient is able to move from older tissue to younger tissue where that nutrient is needed for growth. These mobile nutrients include nitrogen, phosphorus, potassium, magnesium and molybdenum. Immobile nutrients, on the other hand, do not translocate and include calcium, sulphur, boron, copper, iron, manganese and zinc.

Nutrient mobility, or immobility, is important when diagnosing deficiencies. For instance, if the deficiency appears in old growth, then the deficient nutrient is mobile; if it appears in new growth, it is immobile.

Mobility of nutrients within the soil is closely related to the soil's chemical properties. When there is sufficient water for leaching to occur, water can carry dissolved nutrients which will be lost from the soil profile.

Conclusion

This paper has sought to explain in general terms the interaction of various components in ensuring a healthy soil that supports plant growth through the availability of sufficient nutrients.

Other papers will follow in the next few months that will consider the role of water, carbon and microorganisms. Climate change and soil will also be discussed both as a factor that may cause soil degradation and the possibility of harnessing soil as an important store of greenhouse gasses.

Any opinions or views expressed in this paper are those of the individual author, unless stated to be those of Future Directions International.

Published by Future Directions International Pty Ltd.
80 Birdwood Parade, Dalkeith WA 6009, Australia.
Tel: +61 8 9389 9831 Fax: +61 8 9389 8803
E-mail: cjohns@futuresdirections.org.au
Web: www.futuresdirections.org.au