



SOIL

1.1 | SOIL FERTILITY

INTRODUCTION

Soil is the topmost layer of the earth's crust, which gradually developed through the combined action of soil-forming processes. The parent material from which soil developed, can be one or more of the following: the underlying rock, river or aeolian (wind) depositions, and volcanic ash.

Soil supports plants as it provides, to a varying extent, a favourable medium for root growth; as well as supplying nutrients for plant growth.

Soil fertility, in its simplest definition, is the ability of the soil to make plant nutrients available to plants.

FACTORS DETERMINING SOIL FERTILITY

Soil fertility is determined by the following factors, both individually and jointly:

- The available as well as reserve plant nutrients in the soil such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, manganese, copper, boron, molybdenum, iron and, in certain situations, sodium, chlorine and cobalt. Soil analysis gives an indication of the relative values of these chemical characteristics.
- Factors which influence nutrient availability include soil acidity (pH), clay content, organic matter, aeration, soil moisture, micro-organisms and soil temperature. These are chemical, physical and biological characteristics.
- Restrictive factors such as toxic levels of aluminium, chlorine, sodium, manganese, boron and other substances, excessive acidity or alkalinity, excessive salt concentration (brack) or imbalances of plant nutrients. Soil analysis is necessary to identify these conditions.

Although most of the soil's fertility is found in the topsoil, the contribution of the subsoil should not be ignored. The fertility of the total volume of soil in which the plant roots develop, should be taken into account. For this reason, analysis of the subsoil should also be considered.

SOURCES

The natural sources of available plant nutrients are the remnants of the parent material that supply the inorganic component of the soil, as well as plant and animal residues that supply the organic component.

Rocks / parent material

As the parent material weathers, it not only breaks up physically into smaller fractions, but changes chemically due to the action of oxygen, water and weak acids. In this weathering process, soil is formed with specific characteristics such as colour, texture and structure. Clay minerals are also formed and plant nutrients become more readily available.

Organic matter

Dead plants and animal residues are used as a source of food by microorganisms in the soil — the so-called saprophytes — and in this way are broken down to stable organic matter and humus. Organic matter and humus can, under specific circumstances, be completely broken down to soluble minerals and carbon dioxide. The latter, together with water, forms carbonic acid which contributes to further weathering of the parent material and plant nutrient availability.

Microorganisms

Microorganisms not only cause the breakdown of dead organic matter but also play a role in the mineralisation processes. For example, during nitrification, ammonium nitrogen is converted to nitrate nitrogen. Reduced sulphur from the protein of plant material can be converted to sulphate. The nitrogen-fixing bacteria in the root nodules of legumes can fix atmospheric nitrogen and convert it to nitrate, to the benefit of the host plant.

Water

Water is not only a component of the soil but also plays an important role in soil formation. Hydrolysis of the minerals in the parent material causes chemical weathering. During this process certain minerals are dissolved in water and made available to plants.

Atmosphere (air)

Air contains nitrogen (N_2), but in a form that is not available to plants. It must first be converted to ammonium and nitrate before it becomes available to plants. This conversion can be done by lightning and the bacteria in the root nodules of legumes.

The oxygen in air is necessary for the respiration of microorganisms, germinating seeds and plant roots. The oxidation of metals in soil minerals gives some soils their characteristic colour such as red (iron oxide, haematite) and yellow (hydrated iron oxide, limonite).

During the process of photosynthesis in green leaves, carbon dioxide combines with water in the presence of sunlight to form sugars and starches, with the release of oxygen. This is the starting point for the building of the plant's cellular structure and the production of food for man and beast.

COLLOIDS

Humus and clay are made up of very small particles; less than 0.002 mm in diameter. These particles possess special properties and are called colloids. They stick together and are plastic in nature. Due to the small size of colloidal particles their specific surface area is very large. Another important characteristic of colloids is that their surfaces are electrically charged (largely negative). This enables them to attract and hold positively charged ions of dissolved elements (called cations) such as calcium, magnesium, potassium, sodium, ammonium, zinc and hydrogen. This phenomenon is called adsorption. In this way the cations, most of which are plant nutrients, are prevented from leaching. The colloids therefore provide storage for available forms of certain plant nutrients.

The cation exchange capacity (CEC) of a soil refers to the size of the negative electrical charge on the colloids (clay and humus) in a specific soil mass. It is expressed in centimols per kg of soil ($\text{cmol}_c \text{kg}^{-1}$)* and can vary between 1.5 (infertile sandy soil) and approximately 80 or higher (clay soil with a high organic matter content). Many of our good soils have CEC values between 5 and 20 $\text{cmol}_c \text{kg}^{-1}$.

The CEC of pure clay or humus is, of course, higher than that of soil, because soil also contains silt and sand, which do not contribute to the CEC value. The CEC of colloids, expressed in $\text{cmol}_c \text{kg}^{-1}$, is approximately as follows:

Kaolinite (1:1 clay):	5 - 15
Illite (2:1 clay):	15 - 40
Montmorillonite (2:1 clay; swelling):	40 - 120
Humus:	100 - 400

For many soils, the CEC is dependent upon the pH of the soil. As soil acidity increases (pH decreases), more H^+ ions are adsorbed to the colloids. They displace the other cations from the colloids into the soil solution. Conversely, when soils become more alkaline (pH increases), the available cations in solution decrease because there are fewer H^+ ions to displace cations into the soil solution from the colloids (CEC increases) (Havlin, Tisdale, Beaton, Nelson, 2011).

* Centimol per kg soil indicates the same numerical value as the old term milliequivalents per 100 g soil ($\text{me } 100 \text{ g}^{-1}$)

MAINTENANCE

Soil fertility can be modified to a certain extent, for example, a soil can be exhausted or impoverished through mining the soil of nutrients and cultivation practices that break down soil structure. The good farmer, however, is in a position when necessary to build up and maintain soil fertility for sustainable economic crop production. One thinks here in particular of sound practices such as fertilization, liming, soil preparation and moisture conservation.

YIELD CAPACITY

Soil fertility should not be confused with soil potential or the production potential of a specific field. The true ability of a field to produce is determined by a combination of soil fertility and potential.

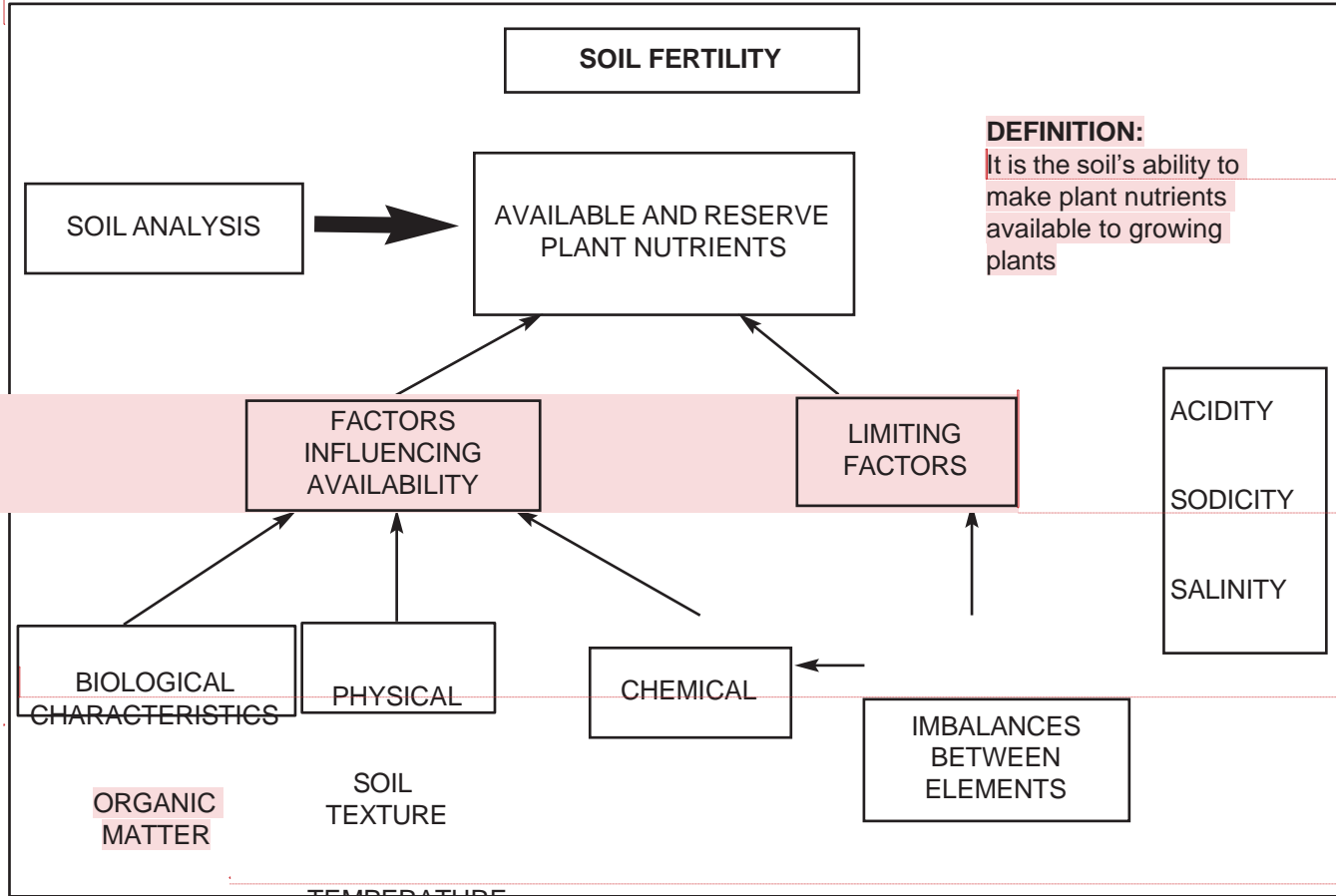
A soil which has a high production potential and which at the same time is fertile can naturally produce high yields. If such a soil is, however, impoverished as a result of exploitation, acidification and leaching, its full potential will not be achieved without improving its fertility. One or more of the following inputs will need to be applied, depending on the nature of the infertility: fertilizer, manure, crop residues, lime and gypsum. A fertile soil on the other hand, can perform poorly if the potential is low, for example due to shallowness or low rainfall.

Whereas soil fertility is dependent on chemical characteristics, potential is determined mainly by physical soil characteristics and environmental factors.

In order to evaluate the fertility of a soil, it must be analysed and the analytical data interpreted according to established norms. This applies particularly to the chemical characteristics as well as certain physical features. These will be dealt with again in subsequent chapters.

REFERENCE

HAVLIN, J.L., TISDALE, S.L., BEATON, J.D., & NELSON, W.L., 2011. *Soil Fertility and Fertilizers*. New Delhi: PHI.



DEFINITION:
It is the soil's ability to make plant nutrients available to growing plants

SCHEMATIC SUMMARY

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