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Soil Types and their Effect on Germination and Emergence of Plant Seeds

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Abstract

Soil types have a huge influence on germination and the emergence of plant and tree seeds. Soil is formed through weathering of the parent rock material. This normally happens when the rocks are exposed to agents of erosion such as wind and rain. The quality of any soil is critical for seed germination to be successful. This is because of its influences on air circulation, water retention and nutrient absorption rate and availability. There are chemical, physical and biological soil quality indicators. This article was a review of different soil types and their impact on germination and emergence of plant seeds. Dark clays form from the crystallization of minerals from molten materials under high temperatures and pressure. Climate, slope and relief also influence soil formation. The physical properties of soil such as texture, structure, depth, consistency, color, permeability and porosity were identified as having influence on the germination and emergence of plant seeds in different soil types. Organic matter rich clay soils had a 75 percent germination of the African giant sunflower. While soil type had an influence on germination of the Amaranth plant, it is crusting that strongly reduces germination. *Helianthus annus* L had lower seed germination due to poor aeration and water logging. Plant species such as *Acacia sieberana* had best germination in sand soil and lower in clays while Cola nitridated could be propagated in any soil type.

Keywords: Emergence, Germination, Properties, Soil, Weathering

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Introduction

Soil is very important for the life kingdom on earth. Neal *et al*, (2016), define soil as unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Soil uses may have physical limitations such as compaction, salinity, texture, acidity, dryness, erosion hazard, sodicity, shallowness and lack of fertility (Osman, 2013). Texture, compaction, shallowness and dryness affect germination while salinity, acidity and lack of fertility may affect emergence and ultimately growth of both seedlings and plants. Soil's physical, chemical and biological properties directly or indirectly affect plant growth, nutrient and water absorption, eventually affecting plant growth and yield (Fageria et al., 2011). This review on the effect of soil types on germination and emergence of plant seeds is crucial as it highlights soil management practices that help reduce soil losses through erosion. Crop productivity can only increase if soil acidity, salinity and fertility are kept under check and control. Soil as well is a habitat for a number of living microorganisms such as bacteria and fungi which are beneficial and symbiotic with some plants. These more than ten million soil organisms per gram of fertile soil transform the soil into a highly active biogeochemical reactor (Blume et al., 2016). When the interdependence of soil flora and fauna is disturbed, one of the soil functions like nutrient cycling, water infiltration, and decomposition are negatively affected, potentially leading to soil degradation and loss of agricultural productive capacity (Ruiz et al., 2008)

Soil Formation

Soils differ from one part of the world to another and even from one backyard to another because of how and where they are formed (SSSA, 2024). Mineral soil is formed by the chemical and physical weathering of rocks (Eldor, 2015). Dark, clayey and base-rich soils are formed from minerals that crystallize early from molten materials under high temperatures and pressures (Schaetzl and Anderson, 2005). Granite, sand and finest clay particles are found from soils that have formed from granite (Neal et al., 2016), while soils from limestone mostly contain insoluble shaley materials that were included as gray mud in more weatherable rock mass. New soil horizons and changes occur through transformations (such as weathering and mineral formation, decomposition and humification), and also through transport processes (Blume, et al., 2016). According to InTeGrate Modules (2018) the most important factors that influence soil formation include climate, soil age, parent material and soil slopes, relief and soil depth. These factors are the reason why soil differs from one place to another because of different influences they have. Parent materials influence soil formation through mineralogical composition, texture and stratification (Schaetzl and Anderson, 2005). Climate controls the rates of chemical reaction and substance transported in the soil, thereby directly affecting the flora and fauna of the soil (Stefaan et al., 2022).

Importance of soil quality on seed germination

Soil quality is the ability of soil to supply plants with essential nutrients at every growth stage, crucial for maintaining agricultural productivity (Radwa et al., 2024). The quality of any soil is very critical for seed germination to be successful. It influences air circulation, water retention and nutrient absorption rate and availability. Quality soil is able to regulate water, sustain plant and animal life, filters and buffers potential pollutants and cycles nutrients (Pathfinders, 2025). Efforts made for vegetation to successfully germinate will be in vain without fertile and nutritious soil (Spraygrass Australia, 2025).

Soil Quality Indicators

Soil quality indicators are soil measurements that can represent the conditions of the system or the soil's ability to perform system functions (USDA, 2015). According to Sahil et al., (2023), soil quality indicators can be categorized into physical, chemical and biological indicators. Elke et al., (2013) listed soil health indicators as chemical, physical, biological, microbiological and biochemical as well as faunal indicators. Bunnemann E. K. et al., (2018) list examples of physical indicators as bulk density, texture, soil depth, bulk density, porosity, particle density, aggregation, infiltration, water storage, soil temperature; chemical indicators include pH, electrical conductivity, heavy metals, base saturation, cation exchange capacity, major and micronutrients, organic pollutants, salinity and sodicity. For biological indicators, he listed soil respiration, nematodes, earthworms, root health, metabolic quotient, soil fauna diversity and microbial biomass. NRCS (2011) states examples of physical indicators as bulk density, infiltration, soil crusts, available water capacity, soil structure and staking; chemical indicators to include electrical conductivity, soil nitrate, pH while biological indicators include earthworms, respiration, soil enzymes, particulate organic matter and potentially mineralizable Nitrogen

How to improve soil quality

Soil quality is improved in various ways such as performing a soil test, adding organic matter, using cover crops, adding minerals to the soil and adding quality topsoil (Alsoils + Ltd, 2022). For Evergreen Trees Direct (2024) four tips for improving soil quality before planting include amending soil with organic matter, improving soil drainage, testing and balancing soil pH and considering soil structure and aeration. According to Swasya Living (2024), soil quality can be improved by adding organic matter, adjusting pH levels, practicing crop rotation and minimizing soil disturbance. These enhance the soil's physical, chemical and biological properties. Rochgro (2025) states four ways that improve soil quality as testing it-the basic test of which is pH, adding compost, mulching the surface and crop rotation. Woodyard and Kladivko (2017) state four strategies to improve field's soil health as practicing no tillage or strip tillage, adding more crops to your rotation, inducing cover crops and managing nutrients

Soil Composition

Soil composition fluctuates daily but is heterogeneous in that it is made up of different components such as 5% organic matter, 45% minerals, 20 – 30% air, 20 - 30% water (University of Hawaii, 2024). Charlotte (2009) concurs with this when she states that a good soil to grow agricultural plants has around 45% minerals, 25% air, 5% organic matter and 25% water. However, CUCE (2008) differs with University of Hawaii (2024) and Charlotte (2009) on soil organic matter when it states that most of their productive agricultural soils (in the United States) have between 3 and 6 percent organic matter. Soil organic matter is basically composed of carbon, hydrogen, oxygen and has small amounts of other elements like nitrogen, phosphorus, sulphur, potassium, calcium and magnesium contained in organic residues (Anil et al., 2019). Water and air levels of 25% are between the ranges of 20 – 30% as stated by Hawaii University (2024). However, De Gomez et al., (2019) also approximated soil components into certain ranges as 45 to 9% of minerals, 2 to 50% water, 1 to 5% organic matter, 2 to 50% air and microorganisms are approximately 1% of soil volume. Soil organic matter consists of varying proportions of small plant residues, small living soil organisms, decomposing (active) organic matter, and stable organic matter (humus) in varying stages (USDA, 2014). Australian soils have low soil organic matter content by global standards except well managed pastures and irrigated systems unconstrained by water availability (Frances, 2013). They contain between 0.3 percent carbon for desert loams while dryland agricultural soils contain about 0.7 to 4.0 percent organic carbon content depending on soil bulk density. In southern Europe, 74% of the land has a surface horizon (0-30cm) that contains less than 2 percent organic carbon (3.4% organic matter) (Ezio et al., 2001). This decline in organic matter contents of many soils as a result of intensive cultivation has now become a major process of land degradation

Effect of soil organic matter on seed emergence

Soil organic matter is any material produced originally by living organisms from plant animals that is returned to the soil and goes through the decomposition process (Bot and Benites, 2005). Humus, which is organic matter that has been converted by microorganisms to a resistant state of decomposition, improves soil fertility by acting as a reservoir for nutrients, increasing the water holding capacity of the soil, improving soil structure and friability, and providing a source of energy for soil living organisms (Mosaic AgriSight, 2021). EDN (2023) concurs with Mosaic AgriSight, (2021) when he states that "soil texture and organic matter content impact the water holding capacity of soils and therefore germination of seed". In sandy soils, there is poor seed to soil contact which causes insufficient moisture for seed germination. While Carter (2002) agrees with EDN (2023) and Mosaic AgriSight (2021), he goes on to elaborate that organic matter also reduces crusting, improves aggregation, prevents erosion and prevents compaction.

Soil Types

There are different types of soils namely clay soil, sand soil, peat soil, silt soil, loam soil and chalky soil (Masterclass, 2022). Clay soil contains at least 25 percent of clay and is good at holding nutrients due to the microscopic structure of each clay particle (Marthar, 2025). Loam soil is a mixture of sand, silt and clay, whose combination works to create fertile, rich soil that offsets the negative of the three soils on their own (Earnest, 2020). Silt soil is a light and moisture retentive soil type with a high fertility rating, well drained and has good moisture holding capacity (Boughton, 2025). Peat soil is almost pure organic matter which is porous and excellent at holding water and nutrients (Martha, 2025). Sandy soil is composed of large particles that produce a gritty texture, drains quickly and does not retain nutrients effectively (ThriveFarm, 2025). It therefore makes it suitable for plants such as succulents and cacti, which require well-drained soils. Chalk soil is rich in lime and characterized by their alkaline pH due to high concentrations of calcium carbonate (GeoPard Agriculture, 2025).

Soil physical properties and the role they play in plant growth and development

Texture

It is the relative proportions of sand, silt and clay in a soil (Henry, 1990). According to Fageria et al., (2011), soil texture is the relative proportions of various soil separates such as sand, silt and clay in soil.

Soil structure

It is the arrangement of soil particles (Neal et al., 2016). Thus, it is the arrangement of primary soil particles such as sand, silt and clay into natural aggregates called peds (Schaetzl and Anderson, 2005). Peds are held together and in place through the adhesion of organic substances, iron oxides, clays or carbonates (McCauley et al., 2005). Strong aggregation decreases detachability and transportability of soil particles by water or wind, thereby runoff and soil erosion (Phogat and Dahiya, 2015).

Types of soil structures (within a horizon) include blocky, platy, prismatic, columnar and spheroidal structures (Wolf and Snyder 2003). A detailed look at these types of soil structural types:

(i) **Blocky structure** has soil particles arranged to form block-like units which are about as high as they are high or long (Daniels and Kathrine, 2015). According to Heliae Agriculture (2023), it has aggregates which are square shaped or blocky structural units with sharp edges and the larger the blocks, the higher the likelihood of difficulty water will have to penetrating the aggregates

(ii) **Platy structure** is made up of thin plate like peds, less than 4mm thick, that are parallel to the soil surface (Schaetzl and Anderson, 2005). Typical of compacted soils, platy structure leads to a drastic reduction of water infiltration capacity (Marcello, 2007)

(iii) **Prismatic structure** has particles arranged around a point and bound by relatively flat vertical surfaces (SAMETI, 2012).

(iv) **Columnar structure** has vertical columns of soil that have a salt cap at the top (Unversity of Hawaii, 2024). It is mostly found in soils with excessive sodium because of the dispersing effects of sodium.

(v) **Spheroidal structure** which is considered most suitable for producing crops, is made up of units that have no sharp edges and is mainly available in those soils rich in organic matter (Wolf and Snyder, 2003). The two types of spheroidal structures are granular and crumb structure. Granular structure soil particles are arranged in small and rounded units and are common in surface soils (Daniels and Kathrine, 2015). The soil grains at the soil surface allow water to circulate easily (Heliae Agriculture, 2023). Anderson (2023) also concurs with this when he states that granular particles don't ack together well, allowing more space for water to move through.

Porosity

Soil porosity of soil pore space are the small voids between particles of soil (Larum, 2021). Course textured soils have many large (macro) pores because of the loose arrangement of larger particles with one another (McCauley et al., 2005). Macro porosity is important in the rapid drainage of excess water from the soil after heavy rainfall or irrigation, while micro porosity retains the water required for plant growth (Sheard, 1991)

Bulk density is the oven – dried mass per unit volume of soil as a whole including pore space (Phogat and Dahiya, 2015). It is an important indicator of soil quality, productivity, compaction and porosity, mainly considered useful to estimate soil compaction (Almendro – Candel et al., 2018). Loose, porous soils have lesser bulk densities than tight, compacted soils (Apex Publishers, 2024). Bulk density values are useful in evaluating chemical associations with plant roots that explore a volume of soil rather than a weight of soil (Buol et al., 2011).

Soil consistence or Plasticity

This gives the indication of how soil will react to mechanical manipulation at various moisture contents (Neal et al., 2016). According to Schaetzl and Anderson (2005), consistence refers to the way a soil feels, resistance of soil material to rupture or plasticity, toughness and stickness of puddled soil material.

Soil color

It reflects environmental conditions, soil forming processes and other influences on the soil (Osman, 2013). According to Phogat and Dahiya (2015), soil colour provides valuable information regarding soil conditions and some properties of the soil. For example, the absorption of more solar radiation by dark-coloured soils, warming up faster than light-coloured soils. Soil colour is determined by the chemical coatings on soil particles, the amount of organic matter and moisture content in the soil

(Charlotte, 2009). Soil colour is determined by the organic matter content, drainage conditions, degree of oxidation as well as presence of specific minerals in some cases (MPCA, 2022).

Soil depth

This refers to the distance from the soil surface to the underlying bedrock, parent material or other hard and compacted material (FARMLAB, 2024). Deep soils are important in soil formation, carbon sequestration as well as providing nutrients and water for plants (Chai, 2021). According to Hancock *et al*., (2015), soil depth limits the water storage capacity of a soil and so controls soil biological productivity.

Soil temperature

Soil temperature affects many aspects of soils the main once of which are plant growth on and biological activities and water movement within them (Schaetzl and Anderson, 2005). Its seasonality is hugely significant to soil water balance, to ecosystem functions and also to agronomic practices (Buol, 2011). According to Fageria *et al*., (2011), temperatures in temperate regions often determine the length of the growing season, while cool temperatures in the spring and autumn limit the growing season of warm season crops and hot summer crops limit the season for cool season crops. Below freezing, there is extremely limited biological activity and water does not move through the soil as a liquid (Henry, 1990). Soil temperature also affects the decomposition of organic matter and soil organic matter which approximately doubles for about every 10^{o}C in the growing range of 13 – 35^{o}C (Wolf and Snyder, 2003).

Soil permeability

This is a measure of the ease with which air and water move through the soil (Apex Publishers, 2024). Other than being a case with which soil allows fluid to pass through it, Phogat and Dahiya (2015) state that permeability also helps in determining the movement and retention of water, nutrients and air. Voids ratio, distribution of inter – granular pores and degree of saturation are among many factors that affect soil permeability (Elhakim, 2016). According to Liz *et al*. (2019), the factors that mainly affect soil permeability are porosity, aggregation, shrinking and swelling of clay particles dispersion caused by low calcium levels versus sodium and magnesium and traffic.

Effect of soil type on seed germination and emergence

Different soil types differ on the impact they have on seed germination and emergence.The African giant sunflower variety has a germination percentage of 75% when sown on dark colored organic matter-rich silty clay loam soils (Yerima, 2015). In amaranth, soil type has an important role in germination but surface soil crusting strongly reduces emergence (Gomes et al., 2022). Soil type also has an impact towards germination and emergence of some tree species such as *Acacia sieberana*. According to Pahla *et al*., (2014), germination percentage of Acacia siebrana seed sown in clay soil is generally lower than that of the same seed in sand soil. *Cola nitida*, a tree species whose major challenge in propagation is linked to germination (Yakubu et al., 2014) was tested for germination in different soil types. These soil types were riversoil, topsoil, topsoil combined with carbonized sawdust and topsoil combined with river soil. However, there were no significant differences on germination of the *Cola nitida seed* among the four soil types (Mukah et al., 2021). Any of the soil types can be used when propagating the large African tree.

According to Conrad et al., (2003), clay soils account for lower seed germination of Helianthus annus L. due to poor aeration, water logging and an impervious layer due to closely packed structure of the soil. For pyrethrum seed, germination will be best on slightly alkaline clay loam soils whose nutrients are moderate (Barbra, 2014).

Conclusions

Good soil management practices should be the priority of not only soil ecologists but also the farming community if the soil is to remain usable and productive. Parent material has an influence in the formation of soil. Physical properties such as texture, structure, depth, color, temperature and permeability are key in seed germination and emergence. Germination of plants like amaranth is poor in soils that crust while African giant sunflower has a very high germination rate of 75 percent if planted with silt clay loam soils with dark colored organic matter. Clay soils account for lower germination percentages of most plant seeds while sand soils have the highest plant seed germination.

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References

Almendro – Candel M.B., Lucas I. G., Navarro-Pedreno J., Zorpas A.A., (2018). Physical Properties of Soils Affected by the Use of Agricultural Waste. Agricultural Waste and Residues.

Alsoils. Ltd (2022). 4 Tips for improving soil quality, Windmill Down Farm, Church Lane, Hambledon, Hampshire PO7 4RT, UK.

Anderson A. (2023). Introduction to Soil Science, Soil Structure, Creative Commons

Anil N., Subodh B. R., Subodh B., Sandeep N. (2019). Organic matter and properties of soil in forest and agriculture areas. International Journal of Geography, Geology and Environment 2019; 1(2): 28 -33

Apex Publishers (2024). Soil Management on Organic Farms, Soil Properties, 13004 Hylamore Court, Haymarket, Virginia 20169, USA.

Barbra S., Marin K., Dean B., Zoran U., Slavica D., Dusica D., (2014). Effect of soil type on seed germination., Journal of Plant Protection Research., Vol. 54, No. 4 (2014)

Blume H.P., Brummer G.W., Fleige H., Rainer H., Kandeller E., Kogel-Knabner I., Kretzschmar R., Stahr K., Wilke B.M. (2016). Soil Science. Springer Heidelberg, New York Dortrecht, London

Bot A., Benites J. (2005). The importance of soil organic matter. Key drought-resistant soil and sustained food production. FAO Soil Bulletin. Viale delle Terme diCaracalla, 00100 Rome, Italy

Boughton (2025). Soil types. British Association of Landscape Industries (BALI), United Kingdom

Bunemann E. K., Bongiorno G., Bai Z., Creamer R. E., de Goede R., De Deyn G., Fleskens L., Geisen V., Kuyper T. W., Mader P., Pulleman M., Sukkel W., van Groenigen J. W., Brusaard L. (2018), Soil Quality – A critical review, *Soil Biology and Biochemistry*, 120, 2018, pp 105 – 125

Buol S. W., Southard R. J., Graham R. C., McDaniel P. A. (2011). Soil Genesis and Classification, Sixth Edition, John Wiley and Sons Ltd. The Atrium, Southern Gate, West Sussex, U.K.

Carter M.R., (2002). Organic matter and aggregation interactions that maintain soil functions. Soil quality for sustainable land management. *Agron. J*., 94: 38 – 47

Chai N. Y., Hao J., Lopes L. D., Ordonez R. A., Wrright E. E., Archontoulis S., Schachtman D. P. (2021). The effects of soil depth on structure of Microbial communities in Agricultural soils in Iowa (United States), American Society for Microbiology Volume 87 Issue 4 e20673 – 20

Conrad A. O., Mcdonald I., Ikponmwosa A. O. (2003). Effect of soil types on the seed germination of Helianthus annus l., Department of Biological Sciences, Federal University of Technology, Yola, Adamawa State, Nigeria

Cornell University Cooperative Extension (CUCE) (2008). Soil Organic Matter, Agronomy Fact Sheet Series, Department of Crop and Soil Sciences, Nutrient Management Spear Programme, http://nmsp.css.cornell.edu

Daniels W.L. Kathrine H. C. (2015). The Mid-Atlantic Nutrient Management Handbook Chapter 3. Concepts of Basic Soil Science, Department of Soil and Environmental Sciences, Virginia Tech. ResearchGate

DeGomez T., Kolb P., Kleinman S.(2019). Basic Soil Components, Climate Woodlands, New Technologies for Agriculture Extension, U.S. Department of Agriculture

Earnest (2020). Different Types of Soils, Different Uses, Earnest Agriculture Inc. Champain, IL

Echo Development Notes (EDN) (2023). Factors that impact seed germination, http://edn.link/93d29y

Elke J. B. N. C., Rafael L. F. V., Daniel B., Marina Y.H.M., Christiane A. d. S., Paulo R. L. A., Alessandra M. d. P., Andre S. N., Jamil d. M. P., Marco A. N.(2013). Soil health: looking for suitable indicators. What should be considered to assess the effect of use and management on soil health? Scientia Agricola. Microbiologia do Solo, Av Padua Dias, 11, C.P. 09 – 13418-900 – Piraccicaba SP – Brasil

Evergreen Trees Direct (2024). 4 Tips for Improving Soil Quality Before Panting, Nursery and Garden Supplies Wholesale, 300 Wooralla Dr, Mornington, VIC 3931, Austarlia

Eldor A. P. (2015). Soil Microbiology, Ecology and Biochemoistry, 4th edition, Colorado State University, Fort Collins, CO 80523, USA. Elsevier

Elhakim A. F. (2016). Estimation of soil permeability. Department of Public Works, Cairo University, Giza, Egypt, Alexandria Engineering Journal (2016) 55, 2631 – 2638.

Ezio R., Robert J., Giovani B. (2001). Organic Matter in the soils of Europe: Present status and future trends, European Communities, European Soil Bureau, Soil and Waste Unit, Institute for Environment and Sustainability, JRC Ispra, Italy

Fageria N.K., Baligar V. C, Jones C. A.(2011). Growth and Mineral Nutrition of Field Crops. Third Edition, Taylor and Francis Group, USA

FARMLAB (2024). What is the soil depth layer? Australian Carbon Industry, farmlab.com.au

Frances H. (2013). Managing soil organic matter, A practical guide, Grains Research & Development Corporation, Department of Agriculture and Food Western Australia

Garrison S.(2024). Soil Formation, Encyclopedia of Britannica

GeoPard Agriculture. (2025). Types of soils and their characteristics in agriculture. Neusser str. 472, Cologne North Rhein-Westfalia 50733. Germany

Gomes V. E. V, Lindsey L. E., Mosquita R. O. (2022). Effect of soil type and sowing depth on the germination and early growth of two grain amaranth cultivars, Agroecosystems, Geoscience and Environment, Department of Plant Science, University of Ceara, Brazil

Hancock G., Willgoose G., Cohen S. (2015). Soil depth and topography: a field assessment of evolutionary controls in a small catchment. Geophysics Research Abstracts. The University of Newcastle, School of Environment and life sciences, Australia

Heliae Agriculture (2023). Soil Compaction Solutions: How Soil Microbes Improve Soil Structure, 618 German Road, Gilbert, AZ85297

InTeGrate Earth focused Modules (2018). Soil Formation and Geography, Future of Food Instructor Materials, https://serc.carleton.edu/196611

Larum D. (2021). Soil Porosity, Gardening Know-How, 130 West 42nd Street, New York, NY 10036

Liz S., Joe R., Walt S. (2019). Permeability and Infiltration. Soil Health Nexus, North Central Region Water Network, USA.

Marcello P. (2007). Soil Structure, The Abdus Salam International Centre for Theoretical Physics, College of Soil Physics

Martha S. (2025). 6 Types of Soil - Plus, the Best Plants to Grow in Each, Dotdasch Meredith Publishing

Masterclass (2022). 6 Soil Types: How to Prepare Different Soil Types for Gardening, Home and Lifestyle

McCauley A, Jones C., Jacobson J. (2005). Basic Soil Properties, U.S Department of Agriculture, Montana State University Extension Service

Minnesota Pollution Control Agency MPCA. (2022). Soil physical properties and processes, MediaWiki, USA

Mosaic AgriSight (2021). Five Benefits of Soil Organic Matter, 101East Kennedy, Blvd, Suite 2500, Tampa, FL 33602

Mukah E. F., Osuagwu G.G.E., Alwell P. (2021). Effect of Soil Types and Mechanical Scarification on the Germination and Seedling Growth of *Cola nitida* Schott &Endl. College of Natural Sciences, Michael Okpara University of Agriculture, Umdike, Nigeria

Natural Resources Conservation Services (NRCS). (2011). Soil Quality for Environmental Health. Soil Quality Indicators: Measures of Soil Functional State, Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, USA

Neal S. E, Thomas J. S., Deb O D. Evah O. D. (2016). Soil Science Simplified, Wiley Blackwell, Hoboken, New Jersey

Osman K. T., (2013). Soils Principles, Properties and Management, Department of Soil Science, University of Chittagong, Bangladesh, Springer

Pahla I., Muziri T., Chinyise T., Muzemu S., Chitamba J. (2014). Effects of Soil Type and Different Pre-sowing Treatments on Seedling Emergence and Vigor of *Acacia sieber ana* Department of Horticulture, Midlands State University, P. Bag 9055, Gweru, Zimbabwe

Pathfinders resource Conservation & development, Inc (2025). The Importance of Soil Quality, 304 South Marple Fairfield, Iowa 52556, United States of America

Phogat V. K., Dahiya R. (2015). Soil Physical Properties. CCS Haryana Agricultural University. ResearchGate

Radwa A., Behairy I., Hasmaa W.E. A., Ahmed A. E. B., Mohamed M., I., Elsayed S. M., Dmitry E. K., Mohamed S.S. (2024). How can soil quality be Accurately and Quickly studied? A Review. *Agronomy 2024, 14, 1682*. MDPI

Richgro (2025). Not all soils are equal: 4 ways to improve your soil quality. 74 Pitt Street, Sydney, NSW, 2000

Ruiz N., Lavelle P., Jimenez J., (2008). Soil Macrofauna Field Manual Technical Level, Food and Agriculture Organization of the United Nations, Rome, Italy

Sahil S., Balara L., Shubham and Shilpa K., (2023), Soil Quality Indicators: A Comprehensive Review. *International Journal of Plant & Soil Science*; Vol. 35, no. 22, pp 315 – 325, 2023

Schaetzl R., Anderson S. (2005). Soils Genesis and Geomorphology, Cambridge University Press, New York

Sheard R. W., (1991). Soil Structure, Density and Porosity, Understnding Turf Management, Pesticide Safety Training Seminar, 45 Walman Drive, Ontario, Canada

Soil Science Society of America (SSSA) (2024), Soil formation, CHLORPT for short! 5585 Guilford Road, Madison, WI 53711

State of Agricultural Marketing and Extension Training Institute (SAMETI) (2012). Soil Science, Department of Extension Education, Birsa Agriculture University, Jharkhand, India

Spraygras Australia (2025). Why is Soil Quality important for vegetation, 7 SENNA ROAD, Wingfield, South Astralia. info@sgaus.com.au

Stefaan D., Stephan M., Seppe D., (2022), Factors of soil formation: Climate, Department of Earth and Environmental Science, University of Leuven, Leuven, Belgium, Elsevier Ltd

Swasya Ltd (2024). Soil Quality Indicators and How to Improve Them: A Comprehensive Guide, Velisha Venture Pivate Limited, #212/766, Chikka Begur Village, Bengalore – 560068

ThriveFarm (2025). Understanding Soil Types: A Comprehensive guide, 73 Wilcot Rd, Simsbury, CT 06070

Unversity of Hawaii (2024). Soil Nutrient Management for Maui County, College of Tropical Agriculture and Human Resources, http://courses.soil.ncsu.edu/index.php?expand=0

United State Department of Agriculture (USDA) (2014). Soil Organic Matter, Soil Health – Guides for Educators, Natural Resources Conservation Services

USDA (2015). Soil Quality Indicators. Chemical Indicators and Soil Functions. USDA Natural Resources Conservation Service

Wolf B., Snyder G. H. (2003). Sustainable soils. The Place of Organic Matter in Sustaining Soils and Their Productivity. Food Products Press. London

Woodyard J, Kladivko E. (2017). Four Strategies to Improve Your Field's Soil Health, Purdue Extension, Indiana Soil and Water, Purdue University.

Yerima B.PK., Tiamgne Y. A., Fokou L., Tziemi T.C.M.A., Van Rast E. (2015). Effect of Substrates on germination and Seedling Emergence of Sunflower (Helianthus annuus L) at the Yongka Western Highlands Research/Garden Park, Bamenda-Cameroon, Tropicultura, Department of Soil Science, Dschang, Cameroon

Yakubu F. B, Adejoh O. P., Igboanuggo ABI. (2014). Vegetative propagation of Garcinia kola (Heckel). World J. Agric Sci 10(3): 85 – 90.