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INFLUENCE OF SOIL FACTORS ON PLANT GROWTH AND DEVELOPMENT

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Abstract
Soil is the primary medium that provides plants with water, mineral elements, oxygen, and conditions for root system development. The aim of this article is to analyze the influence of physical, chemical, and biological soil factors on plant growth and development. Mechanical composition, structure, moisture, temperature, acidity, humus content, mineral nutrition, salinity, and soil microflora activity are considered. It is shown that optimal soil conditions enhance root growth, photosynthesis, plant resistance to stress, and productivity, whereas salinization, compaction, moisture deficiency, and pH imbalance reduce the intensity of physiological processes.

Keywords: Soil, plant growth, plant development, humus, pH, salinity, moisture, fertility, mineral nutrition.

Introduction

Soil is a complex natural system in which physical, chemical, and biological processes occur simultaneously. For plants, it performs supporting, nutritional, water-regulating, and biological functions. Therefore, soil quality is one of the main factors determining seed germination rate, root development, leaf formation, flowering, fruiting, and overall productivity.

Plant growth is associated with an increase in mass and size of organs, while development reflects the progression through life stages from germination to seed formation. At each stage, plants have specific requirements for the soil environment. During germination, moisture and temperature are crucial; during active vegetative growth, nitrogen, phosphorus, and potassium availability is key; and during flowering and fruiting, stable water conditions and micronutrient availability are essential.

The relevance of this topic is due to the fact that many agricultural lands are subject to degradation, erosion, salinization, compaction, and loss of organic matter. These processes reduce soil fertility and limit plant productivity, especially in arid regions. Studying soil factors is necessary for developing rational agricultural practices and increasing the sustainability of farming.

Research Objective:

To summarize the influence of major soil factors on plant growth and development and determine their practical significance for yield formation.

Materials and Methods

An analytical and generalizing method was used in this work. Information from soil science, plant physiology, agrochemistry, and plant ecology was systematized. The analysis was conducted across three groups of factors: physical, chemical, and biological.

Physical factors included mechanical composition, structure, density, moisture, aeration, and soil temperature. Chemical factors included acidity (pH), humus content, macro- and micronutrients, and salinity level. Biological factors included soil microflora activity, mycorrhiza, nitrogen-fixing bacteria, and organic matter mineralization processes.

Table 1. Main soil factors and their influence on plants

Factor Group	Indicator	Optimal Condition	Effect on Plant
Physical	Structure	Granular, рыхлая (loose)	Improves root penetration, water and air exchange
Physical	Moisture	Moderate, no waterlogging	Maintains turgor, transport, photosynthesis
Chemical	pH	Slightly acidic or neutral	Increases nutrient availability
Chemical	Humus	Sufficient organic content	Improves fertility, water retention
Chemical	Salinity	Low salt content	Prevents osmotic and ionic stress
Biological	Microflora	High activity of beneficial microorganisms	Accelerates mineralization and nutrient availability

Results

1. Influence of physical soil properties

Physical properties determine the conditions for root system development. Mechanical composition affects water retention and aeration. Sandy soils warm quickly and drain well but retain little moisture and nutrients. Clay soils have high water retention but poor aeration when overwatered. Loamy soils are most favorable as they balance water retention and air exchange. Soil structure directly affects root growth. Well-structured soil facilitates root penetration, oxygen access, and even water distribution. Compacted soil impairs root respiration, reduces nutrient uptake, and slows plant growth.

Soil moisture is a key factor in plant life. Water is necessary for seed germination, photosynthesis, nutrient transport, and maintaining cell turgor. Water deficiency causes stomatal closure, reduced photosynthesis, and slowed growth. Excess moisture leads to oxygen deficiency in the root zone and may cause root rot.

Table 2. Symptoms of unfavorable soil conditions

Soil Factor	Unfavorable Condition	Symptoms	Agricultural Measures
Moisture	Water deficit	Wilting, weak growth	Irrigation, mulching
Aeration	Compaction/waterlogging	Weak roots, slow growth	Loosening, drainage
pH	Acidic/alkaline	Chlorosis, poor nutrient uptake	Liming or gypsum application
Nutrition	N, P, K deficiency	Yellowing, poor flowering	Balanced fertilization
Salinity	High salt content	Osmotic stress, leaf burns	Leaching, drainage

2. Influence of chemical soil properties

Chemical properties determine mineral nutrition. The most important macronutrients are nitrogen, phosphorus, and potassium. Nitrogen is essential for protein and chlorophyll synthesis; phosphorus is involved in energy metabolism and root development; potassium regulates water balance and increases resistance to drought, diseases, and temperature stress.

Soil acidity affects nutrient availability. Most crops grow best in slightly acidic or neutral soils. High acidity reduces phosphorus, calcium, and magnesium availability, while alkaline conditions reduce iron, zinc, and boron availability. Therefore, pH control is crucial.

Humus content reflects soil fertility. It improves structure, increases water retention, supplies nutrients, and supports beneficial microflora. Decreased humus leads to reduced productivity.

Salinity is especially harmful in arid regions. Excess salts create physiological drought conditions and toxic ion effects, reducing growth, photosynthesis, and yield.

3. Influence of biological soil factors

Biological properties are related to bacteria, fungi, actinomycetes, algae, and soil fauna. These organisms decompose organic matter, mineralize nutrients, and form humus. High biological activity stabilizes plant nutrition and improves soil resilience.

Nitrogen-fixing bacteria and mycorrhizal fungi are especially important. They enhance nutrient uptake and stress resistance. However, pathogenic organisms may also be present and harm plants.

Discussion

Plant growth depends on the interaction of multiple factors. Even with sufficient nutrients, plants cannot develop properly if the soil is compacted, waterlogged, or saline. These conditions disrupt root respiration and nutrient uptake.

Maintaining a balance between moisture, aeration, and structure is critical. Optimal moisture supports transport and photosynthesis, while good structure ensures porosity and oxygen availability. Imbalance leads to stress and reduced productivity.

Soil chemical management should be based on analysis. Fertilization without considering pH, humus, and salinity may be ineffective or harmful. Integrated management including organic amendments and crop selection is necessary.

Conclusion

Soil factors have a direct and multifaceted impact on plant growth and development. Physical properties determine root conditions and gas exchange. Chemical properties provide nutrients and regulate their availability. Biological properties support nutrient cycling and soil fertility.

Optimal conditions include good structure, adequate moisture, neutral or slightly acidic pH, sufficient humus, and active microflora. Adverse factors such as salinity, compaction, drought, waterlogging, and nutrient deficiency reduce plant productivity.

To improve productivity, it is necessary to monitor soil conditions, maintain organic matter, apply balanced fertilization, improve structure, regulate water, and select adapted crops.

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