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Soil Fertility Management for Higher Yield

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Soil is a natural dynamic body and loose material or upper layer of earth consisting minerals or rock particles, air, water and organic matter which can support the growth of plants is known as "soil". The major factor that influences the formation of soil is parent material, life forms climate, vegetation time. The soil is formed under specific natural condition and environment. All terrestrial life on earth is based on the based on the soil. It plays vital role in providing essential nutrients, water for plants development and growth. The soil health means the ability of soil to support humans, animals and plants as a living ecosystem. It includes preserving and enhancing the soil's capacity to sustain biological processes like water regulation, nitrogen cycling and stable habitat. A healthy soil has good structure, nutrient availability and the ability to regenerate back from disruption; all are characteristics of healthy soil (Lakaria et al., 2019). Soil fertility is the capacity of soil to supply essential nutrients to plants in adequate amount. The soil consists of a part of minerals, organic matter, water and air. Maintaining the proper balance in soil composition is crucial for supporting vigorous development and plant health.

Soil fertility management

Technique for managing soil fertility involves the application of both organic and inorganic fertilizer. These must be paired with the understanding of how to adjust these methods to local environment in order to increase crop yield and maximize the agronomic use efficiency of nutrients. Inputs should be monitored and managed in accordance with good agronomic principles. This includes employing precisely measured blends of organic and inorganic in conjunction with complementing agronomic techniques including crop sequencing, rotation and tillage, as well as conserving moisture and soil (Vanlauwe et al., 2014).

Types of soil fertility

Mainly three type i.e. inherent fertility, acquired fertility and actual fertility.

- **Inherent capacity:** It is also known as natural fertility. It is the natural capacity of the soil to supply nutrients to plants without external input. The parent material, climate and natural processes like weathering and breakdown of organic materials all contribute to the development of this kind of fertility. The texture, structure, mineral makeup and amount of organic matter in the soil all have a role.
- **Acquired fertility:** The acquired fertility is the fertility created by human activities or soil management techniques, such as the use of fertilizers, manures, liming, irrigation and appropriate cropping patterns. Fertility rises when soil's physical and chemical characteristics are enhance or when nutrients are provided extremely from organic or

inorganic sources. The acquired fertility is the term used to describe this intentionally increased fertility.

- **Actual fertility:** Actual fertility is the amount of nutrients that are immediately available for plant absorption at a given time under exiting soil and environmental conditions. Only a percentage of nutrients in soil are in a form that plants can absorb, even though the soil contains a lot of them overall. Temperature, microbial activity, nutrient solubility and soil moisture all affect true fertility.

Importance of soil fertility in crop production

Effective management of nutrients in soils is needed to feed the 7.3 billion people on the planet. Soil sampling and the use of nutrient application rates based on scientific principles and research are critical components of nutrient management. Soil fertility management aims at maximizing the efficiency of the agronomic use of nutrients and improving crop productivity. This can be achieved through the use of grain legumes, which enhance soil fertility through biological nitrogen fixation, and the application of chemical fertilizers. Whether grown as pulses for grain, as green manure, as pastures or as the tree components of agro-forestry systems, a key value of leguminous crops lies in their ability to fix atmospheric nitrogen, which helps reduce the use of commercial nitrogen fertilizer and enhances soil fertility. Nitrogen-fixing legumes are the basis for sustainable farming systems that incorporate integrated nutrient management (wolf et al., 2013).

Relationship between soil fertility and crop yield

Soil fertility affects crop productivity/yield. Fertile soil supplies nutrients to plants without causing nutrients toxicity or deficiency or nutrient imbalance. Soil fertility and crop productivity can be increased through proper soil nutrient management (SNM), a process that optimizes the use of fertilizer (e.g., chemical fertilizer, compost, and animal manure) as a source of plant nutrients. SNM is aimed at improving soil health at the same time meeting the nutrient requirements of crops. This can be achieved by applying fertilizer in the right amount, using the right source, the correct placement, and proper timing (Rasoulzadeh and Yaghoubi, 2010). Chemical (inorganic) and organic fertilizers (OFs) have been widely used by farmers to supplement soil nutrients. Chemical fertilizers are produced artificially to provide rapid nutrition to plants. Chemical fertilizers contain mineral nutrients in high concentrations (N, P, and K) that are soluble and readily plant- available. On the other hand, OFs are derived from animal manure and crop residues. OF application in soil offers several benefits such as building up soil organic matter, increases soil water holding capacity, reduces soil compaction, increases soil porosity, and improves soil structure (Widowati et al., 2020).

Factor affecting of soil fertility

- **Parent Materials:** The characteristics of the parent rock determine the type of the soil. The soil formed from rock will have more nutrients if the parent rock has more. For example more phosphorus is found in soil formed from calcareous rock than in soil formed from granite rock. Sand and clayey soils are produced from acid igneous rock (such as quartz) and basic igneous rock (such as norite and dolerite, among others).
- **Climate and Vegetation:** Climate and the kingdom of plants are intimately intertwined. Temperature and rainfall have an impact on soil fertility. Leaching causes the nutrients to be lost in regions with high rainfall.
- **Topography:** The geography of the soil affects its fertility as well. In sloppy land, leaching and erosion are most prevalent. It consequently causes that soil's fertility to decline. However, because high land nutrients are deposited in level land, particularly in low land, in soluble form, the fertility of level land increases.
- **Physical Condition of Soil:** The soil with a sufficient amount of organic matter has good aeration and water flow, and plants develop well in this kind of ideal soil state. The soil must be in good physical condition for plants to grow well. It needs enough oxygen,

because low oxygen is harmful or plants and soil organisms. When oxygen is low, organic matter dos not decompose properly, and nutrients do not become available to plants.

- **Soil Age:** Old soils slowly lose their fertility because rainwater and weathering wash away nutrients. Also growing crops again and again without adding manure makes the soil less fertile.
- **Micro-Organism:** Not all microbial activity is advantageous, despite the fact that microbes are crucial in improving soil fertility. Crop yield, soil fertility, and soil health can all be negatively impacted by certain microbes. Pathogenic activity, nutrition loss, toxin generation, and microbial population imbalance are the primary causes of the detrimental impacts.
- **Soil Erosion:** The physical removal of topsoil by wind and water is called erosion. As a result, the soil becomes less fertile, because soil fertility declines as a result of erosion removing the nutrients that are still present in the top layer of the soil (Dadashi et al., 2019).

Management of soil fertility

- **Fertilizers:** The structural and microbiological ecosystem of soil has suffered in recent decades due to intensive farming practices that include fertilizers, pesticides, and insecticides. Chemical fertilizers that plants don't use remain unavailable to them. Algal blooms and water pollution result from chemical fertilizers being washed away and accumulating in water bodies when rainfall occurs shortly after they are applied to the land (Anderson, 1987).
- **Organic matter management:** Soil fertility is based on organic matter. It boosts microbial activity, strengthens soil structure, increases water-holding capacity, and provides nutrients for breakdown**.** Organic fertilizer help reduce the harmful effect of chemical fertilizers. They improve the physical and chemical quality of the soil.
- **Manures:** Animal dung meets the desired amount of nutritional needs and improves the chemical characteristics of the soil. In essence, the chemical characteristics of manure determine its composition. Manure acidity needs to be monitored to prevent issues because it has a detrimental effect on soil. Carbon-rich beef dung optimizes the soil's nutritional value for crops. Long-term manure application raises soil porosity and reduces compaction, which results in a decrease in the bulk density of the soil (Eghball, 2002).
- **Integrated nutrient management (INM):** By sustainably mixing organic, inorganic, and biological fertilizer sources to preserve soil health, enhance nutrient delivery, and boost crop yield, integrated nutrient management (INM) plays a critical role in soil fertility. By improving soil's physical characteristics, chemical makeup, and biological activity, this method improves soil structure, water retention, nutrient cycling, and microbial life—all of which promote long-term fertility. INM uses combination of chemical fertilizers, organic manure, compost, gen manure, crop residues and biofertilizers in proper and balanced quantity which enhanced water retention provide better soil structure and reduced erosion.
- **Crop rotation and diversification:** By restoring soil nutrients, enhancing soil structure, and disrupting pest and disease cycles, crop rotation and diversity increase soil fertility. While diversification through techniques like cover crops and intercropping promotes spatial and functional variety, rotation minimizes nutrient depletion by alternating crops with varied needs. For instance, various rooting depths enhance soil structure and water retention, while legumes absorb nitrogen, which benefits succeeding crops (Zou et al., 2024). The leguminous crops are rotated with crops such as deep rooted crop like corn to naturally replenish soil nitrogen through biological fixation and reducing the need of synthetic fertilizers.
- **Water and irrigation management:** Water is crucial for soil fertility, because it promotes microbial activity, enables nutrient movement, and preserves soil structure for optimum plant development. In order to guarantee that the proper amount of water is

delivered, avoid problems like nutrient leaching or salinization, and maximize crop output and soil health, proper irrigation management is essential. Using sustainable farming techniques that reduce soil erosion and maintain soil fertility is essential to sustaining agricultural production over the long run (Fadl et al., 2024).

- **Reduced tillage and conservation agriculture:** By reducing soil disturbance, it maintains and enhances soil organic matter, strengthens soil structure, and encourages beneficial microbial activity, all of which improve soil fertility. Long-term improvements in soil health, resilience, and production result from these techniques, which also lessen erosion, increase nutrient. Crop leftovers are preserved with little soil disturbance, and over time, they break down to increase soil organic matter. Better soil structure, water retention, and nutrient availability result from this**.** It disrupts soil microorganism and fungal network and earthworm burrows, which improve water infiltration and aeration (Kumar, 2024).
- **Precision agriculture:** Precision agriculture, a paradigm- shifting strategy that uses cutting- edge technologies to maximize resource use, boost agricultural output and reduce environmental effects, is at the forefront of innovation. The integration of sensor- based nutrient management systems, remote sensing technologies and GPS- guided equipment is essential to precision agriculture (Buneman et al., 2006). Unmanned aerial vehicles (UAVs) and satellite photography are examples of remote sensing technologies that offer real- time insights on crop health, soil moisture levels and nutrient status, enabling focused treatments and well informed decision- making. With the use of sensor based nutrient management systems that include automated irrigation controllers, nutrient probes and soil moisture sensors, farmers can precisely monitor and adjust soil fertility parameters, guaranteeing ideal nutrient levels and reducing nutrient leaching.

Conclusion

Soil fertility management plays a vital role in achieving higher agricultural production and maintaining long-term soil health. Proper management of essential nutrients through balanced fertilization, organic manures, biofertilizers, and integrated nutrient management practices helps improve crop growth, yield, and quality. Healthy and fertile soil also enhances water-holding capacity, microbial activity, and nutrient use efficiency, which are essential for sustainable agriculture. Continuous cultivation and excessive use of chemical fertilizers can reduce soil productivity and lead to environmental problems. Therefore, scientific soil management practices such as soil testing, crop rotation, green manuring, and residue recycling are necessary to maintain soil fertility and prevent degradation. Adoption of sustainable fertility management practices not only increases farm productivity and farmers' income but also conserves natural resources for future generations. Thus, effective soil fertility management is the foundation of sustainable agriculture and food security in the modern era.

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