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An Overview on Soil Salinity: Sources, Characteristics, Agricultural Constraints and Management

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ABSTRACT

Soil salinity is one of the most serious environmental constraints limiting agricultural productivity and sustainability, particularly in arid, semi-arid, and coastal regions. The severity of salinization has increased due to climate change, sea-level rise, improper irrigation, poor drainage, and seawater intrusion. Excessive salt accumulation adversely affects soil physical, chemical, and biological properties, leading to osmotic stress, ion toxicity, nutrient imbalance, and reduced water availability for plants. These effects impair seed germination, plant growth, nutrient uptake, physiological processes, and ultimately crop yield. In addition to agriculture, soil salinity threatens freshwater resources, ecosystem stability, human health, and the livelihoods of coastal communities. This review summarizes the current knowledge on the definition, classification, characteristics, and sources of soil salinity, together with its effects on soil properties, plant growth, agricultural production, and soil fertility. Furthermore, the review highlights integrated management strategies, including improved irrigation and drainage, balanced fertilization, organic amendments, salt-tolerant crop varieties, and sustainable land-use practices to ensure the long-term sustainability of salt-affected regions.

Keywords: Saline soil; Salt stress; Osmotic stress; Nutrient imbalance; Soil fertility; Agricultural productivity; Salinity management.

Introduction

Soil salinity is recognized as one of the most serious environmental and agricultural challenges threatening global food security, agricultural sustainability, and ecosystem stability. The continuous accumulation of soluble salts in the soil adversely affects soil quality, plant growth, nutrient availability, water use efficiency, and overall crop productivity. The problem is particularly severe in arid, semi-arid, and coastal regions, where natural processes such as high evaporation, low precipitation, seawater intrusion, and weathering of parent materials, together with human-induced factors including excessive irrigation, inadequate drainage, and inappropriate land management, accelerate salt accumulation in the root zone. In recent decades, climate change, rising sea levels, irregular rainfall patterns, and increasing anthropogenic disturbances have further intensified soil salinization, making it one of the fastest-growing forms of land degradation worldwide. Soil salinity has attracted considerable scientific attention because of its profound effects on agricultural production and environmental quality. Excessive soluble salts increase the osmotic potential of the soil solution, thereby reducing water availability to plants and inducing osmotic stress, ion toxicity, and nutrient imbalance, all of which collectively impair plant growth and reduce crop productivity (Kurth and Devis, 1986).

In addition to its effects on plants, salinity alters soil physical properties by affecting aggregate stability, infiltration rate, hydraulic conductivity, permeability, and soil aeration, ultimately restricting root growth and reducing microbial activity (USDA, 1954). Prolonged salinization also disrupts soil nutrient cycling and biological processes, leading to progressive deterioration of soil fertility and limiting the productive use of agricultural land. Beyond its agricultural consequences, soil salinity has significant environmental and socio-economic implications. Increasing salinity degrades freshwater resources, reduces biodiversity, alters ecosystem functions, and threatens the sustainability of natural habitats. At the plant level, salt stress triggers a complex series of physiological, biochemical, and molecular responses, including osmotic stress, specific ion toxicity, oxidative damage, nutrient imbalance, inhibition of photosynthesis, and disruption of metabolic activities (Kurth and Devis, 1986; Ackerson and Youngner, 1975; Harkman and Tanaka, 1987). Although substantial progress has been made in understanding plant responses to saline environments, the physiological mechanisms governing salt tolerance and adaptation remain only partially understood, necessitating continued research to develop salt-tolerant crop varieties and sustainable management strategies (Thomas, 1980). Effective management of saline soils requires a comprehensive understanding of the sources, classification, physicochemical characteristics, mechanisms of salt injury, and impacts on soil and plant systems, nutrient dynamics, and appropriate soil management practices. Integrated approaches involving salt-tolerant crop varieties, balanced nutrient management, efficient irrigation and drainage systems, organic amendments, and improved land-use planning have been identified as essential strategies for sustaining agricultural production in salt-affected regions. Therefore, continuous research and technological innovations are necessary to mitigate the adverse effects of salinity and ensure sustainable crop production under changing climatic conditions.

This review summarizes the current knowledge on soil salinity, including the characteristics and classification of saline soils, sources of salinity, chemical properties of salts, and effects of salinity on soil and plant growth, physiological mechanisms of salt stress, fertility status of saline soils, major agricultural constraints, and fertilizer management strategies. It also highlights sustainable management practices aimed at improving crop productivity and ensuring the long-term utilization of salt-affected soils.

Salinity

Salinity is one of the most important agro-environmental constraints limiting plant growth, crop productivity, and sustainable agricultural development worldwide. The accumulation of excessive soluble salts in the soil adversely affects soil properties, plant physiological processes, nutrient availability, and water relations, thereby reducing agricultural productivity and ecosystem functioning. Although soil salinity has long existed as a natural phenomenon in many coastal, arid, and semi-arid regions, its severity has increased substantially over recent decades because of population growth, expansion of irrigated agriculture, climate change, sea-level rise, poor irrigation practices, inadequate drainage, and unsustainable land management. Consequently, the utilization and management of salt-affected soils have become major priorities for achieving global food security and sustainable agricultural production. The adverse effects of salinity on plants primarily arise through three interrelated mechanisms: osmotic stress, specific ion toxicity, and nutritional imbalance (Kurth and Devis, 1986). Elevated concentrations of soluble salts reduce the osmotic potential of the soil solution, making water less available to plants even when sufficient soil moisture is present. Simultaneously, excessive accumulation of sodium (Na^+) and chloride (Cl^-) ions may become toxic to plant tissues, while competition among ions disrupts the uptake and translocation of essential mineral nutrients. These combined effects impair photosynthesis, enzyme activity, protein synthesis, and overall plant metabolism, ultimately reducing plant growth and crop yield. Extensive research has investigated the physiological, biochemical, and molecular responses of plants to saline environments, providing valuable insights into the mechanisms of salt tolerance and adaptation (Ackerson and Youngner, 1975; Harkman and Tanaka, 1987).

Nevertheless, the complex physiological processes governing salt injury and tolerance have not yet been fully elucidated. Consequently, developing crop varieties with improved salt tolerance and implementing effective soil and water management practices remain major research priorities (Thomas, 1980). In addition to reducing agricultural productivity, soil salinity has broader environmental consequences. Increasing salinity affects freshwater availability, degrades soil quality, alters ecosystem functioning, and threatens biodiversity. It also influences hydrological processes, sediment dynamics, and the sustainability of both natural and managed ecosystems (Somers, 1997). Therefore, a comprehensive understanding of soil salinity and its impacts is essential for developing integrated strategies that improve agricultural productivity while ensuring long-term environmental sustainability.

Saline Soil

Saline soil is generally described as soil containing excessive amounts of soluble salts that adversely affect plant growth and ultimately reduce agricultural productivity (USDA, 1954). The accumulation of salts in soil may occur through several natural and human-induced processes, including seawater intrusion, weathering of parent materials, irrigation with saline water, and inappropriate agricultural management practices. In coastal regions, additional factors such as irrigation methods, cropping systems, crop management practices, and the physical characteristics of the soil further accelerate the development of salinity. Verma and Agarwall (1995) defined salinity as the total concentration of dissolved salts present in water. The identification of saline soils is primarily based on their physicochemical characteristics. Typically, saline soils exhibit an electrical conductivity of the saturation extract exceeding 4 dS m^{-1}, a soil pH below 8.5, and an exchangeable sodium percentage (ESP) of less than 15 (Brady and Weil, 2002). The soil solution is predominantly composed of sodium chloride (NaCl) and sodium sulfate (Na_2SO_4), which increase the osmotic potential of the soil solution and restrict water uptake by plants. In general, saline soils contain more than 1–2% soluble salts (Tisdale et al., 1999). They are often characterized by the presence of white salt deposits or crusts on the soil surface. Although these soils may retain relatively stable structural properties, the elevated concentration of soluble salts imposes osmotic stress on plants, thereby limiting growth, nutrient absorption, and overall crop performance.

Soil salinity classification

In different soil classification system, salt-affected soils are represented differently and appear on different taxonomical levels (Abrol *et al.*, 1998). In Bangladesh soil salinity classifications on the basis of electrical conductivity are shown in the table 1.

Table l. Classification of soil salinity in Bangladesh (SRDI, 2003).

Salinity Class	EC (dS/m)
Non saline with some very slightly saline (S_1)	2.0-4.0
Very slightly saline with some slightly saline (S_2)	4.1 -8.0
Slightly saline with some moderately saline (S_3)	8.1 -12.0
Moderately Saline with strongly saline (S_4)	12.1-16.0
Strongly saline with very Strongly saline (S_5)	> 16.0

Chemical properties of salt

Salt is chemically identified as sodium chloride (NaCl), one of the most abundant naturally occurring mineral compounds on Earth. Large quantities of sodium chloride are present in seawater, making it the predominant dissolved salt in marine environments. In addition to its natural abundance, salt is widely used as a food seasoning and preservative throughout the world. Sodium, an essential component of sodium chloride, plays a vital role in maintaining normal physiological functions in the human body, including nerve impulse transmission, muscle contraction, fluid balance, and the sodium–potassium exchange mechanism that is essential for normal cardiac activity. From a chemical perspective, sodium chloride acts as a desiccating agent because of its ability to absorb moisture from the surrounding environment. However, it neither releases nor accepts hydrogen ions (H^+); therefore, it is considered chemically neutral and exhibits neither acidic nor alkaline properties (Dhananjay, 2007).

Sources of salinity

Salts in soil and irrigation water may be either

- Naturally present as products of geo-chemical weathering of rocks and parent materials
- Derived directly from sea water by flooding, spray, or intrusion into groundwater resources
- Caused by irrigation mismanagement, particularly when internal soil drainage is impeded (USDA, 1954).

Effects of Salinity on Soil

Soil salinity profoundly influences the physical, chemical, and biological properties of soils, thereby reducing their capacity to support healthy plant growth and sustainable agricultural production. One of the most significant consequences of excessive salt accumulation is the deterioration of soil structure. Under saline conditions, calcium ions (Ca^{2+}), which play a crucial role in maintaining soil aggregation and structural stability, are gradually displaced by sodium ions (Na^+) on the soil exchange complex. This cation exchange weakens the binding forces between soil particles, resulting in poor soil aggregation, reduced aggregate stability, and deterioration of overall soil structure. Consequently, soil porosity decreases, water infiltration becomes slower, soil aeration is restricted, and root penetration is impaired. These adverse structural changes are particularly severe under conditions of high or prolonged salinity. Salinity also modifies the behavior of soil colloids and influences the interaction among soil particles. Moderate concentrations of soluble salts may promote the aggregation of fine soil particles through a process known as flocculation. Flocculation improves soil structural stability, enhances pore continuity, facilitates water movement, and promotes root elongation and gaseous exchange within the root zone. Therefore, under limited salinity, soil aggregation may temporarily improve. However, when soluble salt concentrations become excessive, the beneficial effects of flocculation are outweighed by the harmful impacts of high salinity on plant growth and soil functioning. Excessive salinity increases the osmotic potential of the soil solution, restricts water availability to plants, and creates an unfavorable environment for soil microorganisms and root development. Consequently, maintaining soil structure by increasing salinity is not a practical management strategy because the associated physiological stress severely reduces plant growth and agricultural productivity (USDA, 1954).

Effects of Salinity on Plant Growth

Soil salinity is one of the major abiotic stresses responsible for reducing crop establishment, vegetative development, and final yield. Excess accumulation of soluble salts in the root zone results in poor seed germination, irregular crop establishment, uneven plant stands, stunted growth, and substantial reductions in biomass and grain production. The severity of these adverse effects depends largely on the concentration of soluble salts, the duration of salt exposure, plant developmental stage, and the inherent salt tolerance of individual crop species. The primary consequence of salinity is the reduction in water availability to plants. Although moisture may still be present in the soil, increasing salt concentrations raise the osmotic pressure of the soil solution, making water more difficult for plant roots to absorb. Consequently, plants experience physiological drought despite the presence of adequate soil moisture. In addition to osmotic stress, excessive accumulation of specific ions such as sodium (Na^+) and chloride (Cl^-) may become toxic to plant tissues and interfere with the uptake of essential mineral nutrients, leading to nutritional imbalances and disruption of numerous metabolic processes (Bahner, 2002).

Plant growth does not cease abruptly at a particular salinity threshold; instead, growth progressively declines as salinity increases. Under severe salt stress, plants commonly develop chlorosis, leaf necrosis, reduced photosynthetic activity, and eventually die if the stress persists. Considerable variation exists among plant species and cultivars in their ability to tolerate saline conditions. Therefore, salt tolerance is generally evaluated based on the reduction in crop yield under saline conditions relative to corresponding non-saline environments. Experimental studies have consistently demonstrated that plant biomass decreases with increasing root-zone salinity. Under non-saline conditions, plants produce maximum dry matter accumulation, whereas increasing salinity significantly reduces the dry weight of parent plants, stolons, and daughter plants (Ochiai et al., 2001). Salinity also affects various morphological and physiological characteristics, including reduced plant height, slower growth rate, suppression of apical meristems, decreased leaf area, fewer branches, reduced stem diameter, and lower root and shoot biomass (Zeng and Shannon, 2000; Joolka and Singh, 1979). Salt-stressed plants often appear dwarf with dark green, thickened, or succulent leaves, although external symptoms may not always reflect the severity of internal physiological damage (Mass and Hoffman, 1977).

At the biochemical level, salinity suppresses several important metabolic activities. Salt stress reduces leaf soluble protein concentration, nitrate (NO_3^-) content, nitrate reductase activity, straw yield, grain yield, and grain protein content, thereby limiting overall crop productivity. In rice-growing areas affected by salinity, substantial reductions in plant population and final grain yield have frequently been reported (Shannon et al., 1998). Mass and Hoffman (1977) further reported that once soil salinity exceeds the crop-specific threshold level, both the growth rate and final plant size decline progressively. Moreover, different plant organs do not respond equally to salinity, with shoot growth generally being more severely inhibited than root growth. Increasing soil salinity also causes significant reproductive failure. Shannon (1981) observed that severe salt stress induces leaf injury, structural abnormalities, and ultimately plant death. Rice is particularly sensitive during the panicle initiation stage, when exposure to salinity causes marked reductions in reproductive development and grain formation (Khan et al., 1996). In extremely saline environments, agricultural production becomes almost impossible, resulting in barren landscapes. Moderately saline soils in arid and semi-arid regions generally support only scattered populations of salt-tolerant grasses and shrubs, whereas coastal saline soils in humid tropical and subtropical regions are typically dominated by mangrove vegetation (FAO–UNESCO, 1973). Salinity also adversely affects the earliest stages of plant establishment. High salt concentrations primarily inhibit seed water absorption (imbibition) through osmotic effects, while subsequent reductions in seedling emergence, survival, and early growth are mainly associated with ion toxicity (Zekri, 1993).

1. Osmotic Effect

Osmotic stress is considered the earliest and most immediate consequence of soil salinity, particularly under moderate saline conditions. Salt-induced osmotic stress alters the concentration of numerous organic compounds involved in plant metabolism and stress adaptation (Strogonov, 1973). As soluble salts accumulate in the root zone, the osmotic potential of the soil solution becomes increasingly negative, thereby reducing the soil water potential. This decline weakens the water potential gradient between the soil and plant roots, making water absorption progressively more difficult even when adequate moisture is present in the soil (Jacoby, 1994). Consequently, plants experience physiological drought, resulting in reduced water uptake, loss of cell turgor, inhibition of cell expansion, and a marked decline in growth rate (Peterson, 1961). According to Bernstein (1974), the osmotic potential of the soil solution is a major factor determining plant performance under saline conditions. To survive osmotic stress, plants develop an adaptive mechanism known as **osmotic adjustment**, which involves the accumulation of compatible solutes and inorganic ions within cells to lower their internal osmotic potential. This adjustment enables plants to maintain water uptake from the surrounding saline soil, preserve cell turgor, sustain metabolic activity, and protect cellular structure during stress. Osmotic adjustment is therefore regarded as one of the most important physiological mechanisms underlying plant adaptation to salinity. Salt-tolerant crop species generally exhibit a greater capacity for osmotic adjustment than salt-sensitive species under conditions of low water potential (Saneoka et al., 1999). Moreover, studies have demonstrated that effective osmotic adjustment not only enhances plant survival under saline environments but also improves biomass production, yield, and yield stability by maintaining normal physiological processes throughout the growing season (Morgan, 1995).

2. Specific Ion Toxicity

In addition to osmotic stress, excessive accumulation of specific ions represents another major mechanism by which salinity impairs plant growth and productivity. Normal cellular function depends on maintaining an appropriate balance between monovalent cations, particularly potassium (K^+) and sodium (Na^+), and divalent cations, mainly calcium (Ca^{2+}). Under normal conditions, this ionic balance preserves the selective permeability of cell membranes and ensures efficient transport of water and nutrients. However, excessive accumulation of monovalent ions, especially sodium, disrupts this balance, increases membrane permeability, and causes cellular injury. Salt-induced plant damage therefore results from both reduced soil water potential and the toxic effects of excessive ion accumulation within plant tissues (Zekri, 1993). Elevated concentrations of sodium and chloride ions interfere with numerous physiological and biochemical processes, including enzyme activity, membrane stability, photosynthesis, and nutrient transport. Although ion toxicity is an important component of salt stress, Bernstein (1974) suggested that, for most crop species, growth reduction under saline conditions is influenced more by the overall concentration of soluble salts than by the toxicity of individual ions. Consequently, the combined effects of osmotic stress and ion toxicity ultimately determine the severity of salinity-induced growth inhibition.

3. Nutritional Imbalance

Balanced nutrient availability is essential for normal plant growth, development, and productivity. Under saline conditions, however, excessive accumulation of soluble salts in the root zone disturbs nutrient availability and uptake, leading to nutritional imbalance. High concentrations of sodium and chloride ions compete with essential mineral nutrients for absorption sites on root membranes and interfere with nutrient transport within plants. Since crop species differ considerably in nutrient requirements, ion selectivity, and salt tolerance, the nutritional effects of salinity vary among plant species and cultivars. Khan et al. (1996) reported that increasing salinity significantly reduced the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and zinc (Zn) in plant tissues, whereas magnesium (Mg) content increased up to a salinity level of 8 dS m^{-1} before declining at higher salinity levels. Similarly, Hassan et al. (1970) observed that elevated salinity markedly suppressed potassium and phosphorus uptake in barley. Bernstein (1974) further demonstrated that high concentrations of calcium chloride ($CaCl_2$) in the growth medium significantly reduced potassium and magnesium absorption in bean plants. These findings indicate that salinity-induced nutrient imbalance is an important factor limiting plant growth, physiological performance, and crop yield in salt-affected soils.

Concept on Fertility Status of Saline Soils

The fertility status of saline soils is generally poor because excessive soluble salts adversely influence nutrient availability, nutrient cycling, and soil physicochemical properties. Although the exchange complex of saline soils often contains relatively high levels of exchangeable calcium (Ca) and potassium (K), excessive saturation by sodium (Na) and magnesium (Mg) is frequently observed. High levels of exchangeable sodium deteriorate soil structure, reduce infiltration, and adversely affect nutrient availability, whereas excessive magnesium promotes sodium uptake while simultaneously suppressing calcium absorption because of antagonistic ionic interactions (Ayers and Westcot, 1976). These conditions collectively reduce soil productivity and crop performance.

Nitrogen is commonly the most deficient macronutrient in saline soils. Total nitrogen content is generally very low, largely because of insufficient organic matter accumulation. Continuous cultivation, rapid decomposition of organic residues under favorable conditions, inadequate incorporation of farmyard manure and compost, and substantial losses of ammonium nitrogen through volatilization all contribute to poor nitrogen fertility in salt-affected soils (Mia et al., 2001).

Phosphorus availability in saline soils generally ranges between 15 and 25 ppm; however, in many salt-affected areas the available phosphorus concentration remains below the critical level required for optimum crop growth. Phosphorus distribution within the soil profile is often irregular, with concentrations generally decreasing with depth before increasing again in deeper horizons. Sulfur availability also varies considerably among saline soils. Rahaman and Bhattacharya (2006) reported that topsoil sulfur concentrations ranged from 15.0 to 73.9 ppm, with relatively higher sulfur contents frequently observed in coastal soils subjected to regular tidal inundation. Nevertheless, sulfur distribution within individual soil profiles does not usually exhibit a consistent increasing or decreasing pattern throughout the pedon.

Major Agricultural Constraints in Saline Soils

Soil salinity is one of the most important factors limiting agricultural production in salt-affected regions, particularly during the dry season when salt accumulation in the root zone reaches its maximum level. In many coastal areas, extensive tracts of agricultural land are regularly influenced by tidal saline water intrusion, creating unfavorable conditions for crop cultivation. The lack of effective and site-specific management practices for saline soils further aggravates this problem. In addition, the scarcity of good-quality irrigation water during the dry season severely restricts the cultivation of Boro rice**,** Rabi crops, and even Aus rice during the Kharif-I season, resulting in a substantial reduction in annual cropping intensity and overall agricultural productivity (Rai, 1977). The fertility status of most saline soils is generally poor, with low to very low levels of organic matter, nitrogen, phosphorus, and essential micronutrients such as zinc and copper. Consequently, crop productivity in these soils remains considerably lower than that of non-saline agricultural lands. Agricultural production is further constrained by large year-to-year variations in rainfall, uncertain onset and withdrawal of seasonal floods, and the frequent occurrence of drought. Delayed rainfall often postpones land preparation and transplanting operations, whereas excessive monsoon rainfall and flash floods damage standing Aus and Aman rice crops. In the coastal saline belt, the winter growing season is comparatively short, making timely sowing of Rabi crops essential. However, delayed harvesting of Aman rice frequently shortens the planting window for winter crops, thereby limiting cropping opportunities and reducing overall farm productivity (Bhumbala et al., 1978).

Another major limitation is the narrow genetic and technological base available for salt-tolerant crop production. The limited availability of salt-tolerant cultivars restricts crop diversification and reduces farmers' options for selecting suitable varieties under saline conditions. Continuous cultivation of the same crop cultivars over successive years also increases the vulnerability of crops to insect pests and diseases. Serious infestations of pests such as hispa, leaf hopper, and tungro virus frequently occur in saline regions, causing significant yield losses almost every year (Das and Mehrotra, 1971). Water management problems also constitute a major constraint in coastal agricultural systems. A considerable portion of the coastal region is protected by polders; however, poor maintenance of embankments, sluice gates, and drainage structures has reduced their effectiveness. Water levels within polders are often not managed according to the requirements of modern crop production systems. Consequently, prolonged waterlogging caused by inadequate drainage and improper operation of sluice gates restricts agricultural land use, particularly in low-lying areas. Moreover, unauthorized excavation of canals for introducing saline water into shrimp ponds has intensified soil salinization and created conflicts between crop farmers and shrimp producers, thereby affecting both agricultural productivity and rural livelihoods (Karim, 1980).

The physical characteristics of saline soils further complicate crop production. Most saline soils possess silty clay to clay textures, which become extremely hard upon drying and develop deep, wide cracks that make land preparation difficult and costly. Mechanized tillage operations are often restricted under such conditions. Furthermore, the dissemination of modern agricultural technologies suitable for saline environments remains inadequate due to limited extension services and insufficient numbers of extension personnel trained in saline soil management. These technological and institutional limitations have significantly slowed the adoption of high-yielding varieties (HYVs) and improved crop management practices in salt-affected areas (Das and Mehrotra, 1971). Despite these numerous challenges, saline coastal regions still possess considerable potential for agricultural development. While certain constraints, such as tidal influence and climatic variability, are natural and cannot be eliminated completely, many physical, technological, and socio-economic limitations can be minimized through improved water management, development of salt-tolerant crop varieties, balanced nutrient management, effective extension services, and integrated land-use planning (BRRI, 1983).

Fertilizer Application in Saline Soils

Efficient fertilizer management is an essential component of crop production in saline soils because the presence of excessive soluble salts substantially influences fertilizer behavior, nutrient availability, and nutrient uptake by plants. According to Abrol et al. (1998), both the method and rate of fertilizer application should be carefully selected under saline conditions because most fertilizers dissociate into soluble ions after application, thereby increasing the salt concentration of the soil solution. This additional contribution to soil salinity varies among fertilizer sources and is commonly expressed as the salt index, which indicates the relative potential of a fertilizer to increase soil solution salinity.

The response of nitrogen, potassium, and micronutrient fertilizers in saline soils is generally similar to that observed under non-saline conditions; however, fertilizer efficiency largely depends on the fertilizer source and prevailing salinity level. Saneoka et al. (1990) reported that urea and ammonium sulfate performed more effectively than calcium ammonium nitrate under saline conditions because they provided greater nitrogen use efficiency and better crop performance. Therefore, selecting appropriate nitrogen fertilizer sources is particularly important for improving crop productivity in salt-affected soils.

Salinity also influences phosphorus availability and uptake. Buehrer (2022) demonstrated that alkali chlorides reduce phosphorus solubility in calcareous soils through interactions with calcium carbonate, thereby limiting phosphorus availability to plants. Similarly, Chhabra and Abrol (1977) observed that sulfate (SO_4^{2-}) and chloride (Cl^-) ions directly compete with phosphate ions for root absorption sites, significantly reducing phosphorus uptake under saline conditions. Consequently, phosphorus deficiency frequently develops in saline soils despite adequate soil phosphorus levels.

Unlike phosphorus, potassium deficiency is generally less common in saline soils because many saline soils naturally contain appreciable quantities of exchangeable potassium. Nevertheless, potassium fertilization, particularly through the application of muriate of potash (MOP), may still be required to maintain proper ionic balance and support plant growth. According to Heiman (2018), interactions among nitrogen, phosphorus, sulfur, and potassium may be either synergistic or antagonistic depending on their relative concentrations within the soil and plant. Therefore, balanced fertilization is essential for maximizing nutrient use efficiency under saline conditions.

Ahmed et al. (2022) showed that supplementing irrigation water with potassium equivalent to approximately 10% of the total salt concentration successfully improved the growth of groundnut and cowpea under moderately saline conditions. However, this beneficial effect gradually disappeared as salinity increased beyond moderate levels, indicating that fertilizer management alone cannot completely overcome the adverse effects of severe salinity. Consequently, successful nutrient management in saline soils requires an integrated approach combining appropriate fertilizer selection, balanced nutrient application, efficient irrigation management, and the cultivation of salt-tolerant crop varieties.

Limitations

This review is primarily based on previously published literature and therefore depends on the quality, availability, and scope of existing studies. Most of the information reviewed focuses on the general aspects of soil salinity and selected studies conducted in Bangladesh; consequently, recent regional variations and site-specific conditions may not be fully represented. In addition, quantitative comparisons among studies were not performed because of differences in experimental conditions, soil types, climatic factors, and methodologies. Future reviews should incorporate more recent publications, meta-analyses, and field-based evidence to provide a more comprehensive understanding of soil salinity and its management under changing climatic conditions.

Conclusion

Soil salinity has emerged as one of the most significant constraints to sustainable agricultural production, particularly in coastal and arid regions. Excess accumulation of soluble salts adversely affects soil physical and chemical properties, plant physiology, nutrient availability, crop productivity, water resources, and environmental quality. In Bangladesh, the expansion of saline-affected areas has become a major threat to food security, especially in the coastal districts where climate change, sea-level rise, saline water intrusion, and inappropriate land management practices continue to intensify the problem. Although considerable progress has been made in understanding the causes and impacts of soil salinity, effective management requires integrated approaches involving salt-tolerant crop varieties, improved irrigation and drainage systems, balanced fertilizer management, organic amendments, and appropriate land-use planning. Sustainable management of saline soils is therefore essential to maintain agricultural productivity, environmental sustainability, and livelihood security in salt-affected regions.

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