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Original Article

Plant Nutrition Affected by Soil Salinity and Response of *Rhizobium* Regarding the Nutrients Accumulation

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Abstract

Identification of nutritional disorders in crops growing on saline soils may facilitate the development of breeding or agronomic practices that improve yields in saline areas. The aim of present review was to study the impact of salinity on the mineral nutrient. Nutrient disturbances under salinity and reduce plant growth by affecting the availability, transport, and partitioning of nutrients. Salinity may cause nutrient deficiencies or imbalances, due to the competition of Na^+ and $Cl^–$ with nutrients such as K^+, Ca^{2+}, and NO_3. In saline soils N is one of the most growth - limiting nutrient. Phosphorus deficiency treatment decreased the whole plant fresh and dry mass, nodule weight, number and functioning. Potassium uptake by plants can be affected by high salinity and the Na concentration in the soil solution. There is abundant evidence that Na and the Na/Ca ratio affects K uptake and accumulation within plant cells and organs and that salt tolerance is correlated with selectivity for K uptake over Na.

Keywords: salinity, *Rhizobium*, nitrogen, phosphorus, potassium.

1. Introduction

Salinity is one of the major abiotic stress hinder the productivity of legumes in arid and semi-arid regions. The accumulation of water salts has a drastic impact on environmental health and economic welfare of the country because 2.8 billion hectares of arable land is compromises by the salinity [3]. According to the FAO Land and Plant Nutrition Management Service, over 6% of the world's land is salt affected (table 1) [9].

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Natural salinity results from the accumulation of salts over long period of time and is caused by two naturalprocesses.First is the weathering process that breaks down rock and release soluble salts of various type, mainly chloride of sodium, calcium and magnesium, and to a lesser extent, sulphates and carbonates. Sodium chloride is the most soluble salt. The second is the deposition of oceanic salt carried in wind and rain [9].

Many legumes nodulate poorly in high saline soils and because of these sensitivities, many studies have been performed to establish the effect of salts on the growth of rhizobia in culture [2]. Saline soils are characterized by the presence of extreme ratios of Na^+/Ca^+, Na^+/K^+, Ca^{2+}, Mg^{2+}, and Cl^-/NO_3^-[13] and high levels of neutral salts in the surface layers resulting from the capillary rise of water [2], excess of soluble salts in the soil leads to osmotic stress, which results in specific ion toxicity [3].

Table 1. Salt affected land in the world

Regions	Total area (Mha)	Saline soils		Sodic soils	
		Mha	%	Mha	%
Africa	1.899	39	2.0	34	1.8
Asia, Pacific and Australia	3.107	195	6.3	249	8.0
Europe	2.011	7	0.3	73	3.6
Latin America	2.039	61	3.0	51	2.5
Near East	1.802	92	5.1	14	0.8
North America	1.924	5	0.2	15	0.8
Total	12.781	397	3.1	434	3.4

Bacteria of genus *Rhizobium* have the ability to colonize the roots system of host plants and form nodules. Inside the nodule bacteria start to fix nitrogen required by the plant. Symbiotic nitrogen fixation involves compatibility between bacteria and host plant. The process begins with the attachments of bacteria to roots with the help of flavonoid released by host plant. These flavonoids can activate the nodulation genes of the rhizobia, which release the Nod factors. They are able to stimulate the plant to allow entering into the root hair [1, 8, 28].

Bacteria attach themselves to epidermal root cells and induce tumor like growths called nodules [4]. Mature nodule is full with billions of di-nitrogen fixing bacteria and within the root hairs they divide repeatedly.

The host plant supplies the energy needed to initiate di-nitrogen fixation by capturing energy from sunlight by the process of photosynthesis [12]. *Rhizobium* strains have a host specificity and they fix N for a particular host plan only [18]. Symbiotic nitrogen fixation seems to be an acceptable, "friendly" with the environment and low cost source of N for legume cultivation.

Legume - rhizobia symbiosis plays an important part in fixing atmospheric nitrogen (N) on crop productivity. Legumes can improve saline soil fertility and help reintroduce agriculture in nitrogen - poor soils. Many legumes are very sensitive to salt levels by the increase in osmotic potential and by the toxic effect of high concentration of ions [20].

Mineral nutrients may influence symbiotic di - nitrogen fixation of leguminous plants at any of four phases of the overall process: host plant growth, growth and survival of rhizobia, infection and nodule development, and nodule function [16]. *Rhizobium* nutrient imbalance may result from the effect of salinity or may be the caused by the physiological inactivation of a given nutrient [13].

Salinity disrupts mineral nutrient acquisition by plants in two ways. First, the ionic strength of the substrate, regardless of its composition, can influence nutrient uptake and translocation. Evidence for this is salinity-induced phosphate uptake in certain plants and cultivars. The second and more common mechanism by which salinity disrupts the mineral relations of plants is by reduction of nutrient availability by competition with major ions (Na^+ and Cl^-) in the substrate. These interactions often lead to Na^+- induced Ca^{2+} and/or K^+ deficiencies and Ca^{2+}- induced Mg^{2+}deficiencies[13].

2. Nitrogen

Nitrogen (N_2) is an essential element for the support of all forms of life. N_2 is the most abundant gas in Earth's atmosphere and can be found in amino acids and proteins and many organic compounds are derived from the nitrogen fixation process [6]. Nitrogen is an essential constituent of proteins, nucleic acids, some carbohydrates, lipids, and many metabolic intermediates involved in synthesis and transfer of energy molecules [21].

Mechanistic explanation of nitrogen fixation can be sought at cellular, physiological and sub ecosystem levels (fig.) [6].

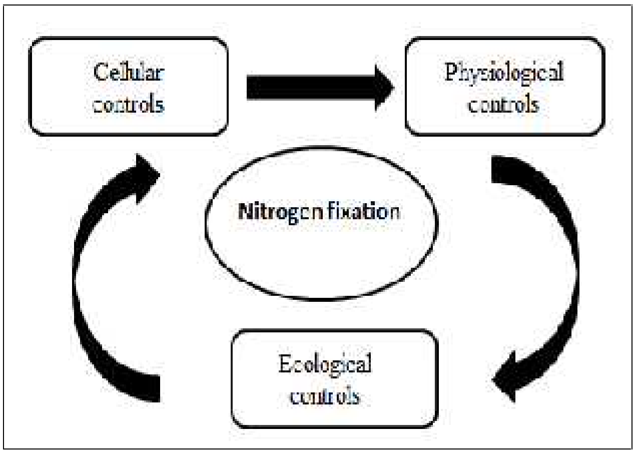

Figure 1. Patterns of Nitrogen Fixation

In plants, up to 25 % of total nitrogen came from nitrogen fixation [6]. Amount of nitrogen fixed depends not only on the genetics of the bacteria but also on the environment and agricultural practices [12]. It is very difficult to measure the amount of nitrogen fixed for two main reasons. First was that symbiosis occurs into the nodules of the roots plants beneath the soil surface, and to make the measurements involves disturbing the root system by digging up the plants.

Second problem was that legumes use soil nitrogen and fertilizer nitrogen as well as nitrogen derived from their symbiotic association. Once soil nitrogen is taken by a legume, the nitrogen from these sources cannot be distinguished from nitrogen from symbiotic fixation [12].

Saline conditions affects survival and proliferation of *Rhizobium*, inhibiting the infection process and directly affecting root nodule function and beside all of this salinity affects photosynthesis and demand for nitrogen [22], the nodulation process is quickly regained after removal of the stress [25]. Salinity affects shoot growth more than root growth [11].

Several hypotheses have advanced to explain the negative effect of salt on nitrogen fixation by diminished photosynthate supply to the nodule, reduced the supply of respiratory substrates to the bacteroids and alterations in the oxygen diffusion barrier [26].

Some studies show that Cl^- inhibited NO_3^- uptake more than $SO_4^{2-}$when this anions were present on an equal osmolarity. In response to salinity NO_3^-concentrations are drastic reduced and other nitrogen-containing either increased or was not greatly reduced [13]. Salt reportedly promotes the accumulation of ammonium, nitrate and free amino acids in plants [26].

3. Phosphorus

After nitrogen, phosphorous is the second major nutrient for plant growth as it is an integral part of different biochemicals like nucleic acids, nucleotides, phospholipids and phosphoproteins. Phosphorus exists in two forms in soil, as organic and inorganic phosphate, and like other nutrient elements such as potassium, iron, zinc and copper, possesses limited mobility in the soil [9].

Interaction between salinity and phosphorus (P) nutrition is maybe more complex or more confusing than the interaction between salinity and N [13]. Phosphorus and N are both involved in vital plant functions such as photosynthesis, protein formation, and symbiotic N fixation.

The primary benefit from band placement of N and P fertilizers is greater P uptake because of increased P solubility and proximity to seedling roots. Also, ammoniacal-N fertilizers canimprove P availability to plants and thereby improve crop growth [5].

Phosphorus (P) is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next.

It is an essential macroelement for the growth of *Rhizobium* bacteria to convert atmospheric N (N_2) into an ammonium (NH_4) form useable by plants. *Rhizobium* is able to synthesize the enzyme nitrogenase which catalyzes the conversion of N_2 to two molecules of ammonia (NH_3) [5]. As a main element in plant growth, phosphorus is one of several elements which affects N_2 fixation, and, along with N, it is a principal yield-limiting nutrientin many regions of the world [29]. In acid or alkaline soils, P always tightly binds with aluminum, iron, calcium and magnesium to form insoluble compounds or sparingly soluble phosphates, and unavailable for plant uptake [17].In soil phosphorus reacts with iron, aluminum and calcium to form insoluble compounds [30].

Salinity decreased the P concentration in plant tissue; in others salinity increased P or had no effect. It is not surprising that these differences among studies occur since P concentrations vary widely in different experiments and other nutrient interactions could be occurring simultaneously [13].

Some studies shows that a variety of *Rhizobium* species can assimilate P at very low solution concentrations ($\leq$ 0.05 µM), similar to those in soil solutions of phosphate-deficient soils [19]. Some strains of rhizobia are P-solubilizing microorganisms (PSM), are able to solubilize unavailable P and increase the yield of crops [10].

Phosphate availability is reduced in saline soils not only because of ionic strength effects that reduce the activity of phosphate but also because P concentrations in soil solution are tightly controlled by sorption processes and by the low solubility of Ca-P minerals.

Therefore, it is understandable that P concentrations in field-grown agronomic crops decreased as salinity (NaCl + CaCl) increased [13].

Excessive P accumulates in sensitive cultivars regardless of the Ca^{2+}/Na^+ ratio and is dependent upon the ionic strength or osmotic potential of the solution regardless of the types of salts used.

Combinations of $NaCl + CaCl_2$, $KC1 + CaCl_2$, or $NaN0_3 + Ca(NO_3)_2$ all produced similar effects [13].

4. Potassium

Potassium is an essential factor in protein synthesis, glycolytic enzymes, and photosynthesis; an osmoticum mediating cell expansion and turgor-driven movements; and a competitor of Na^+under saline conditions. Because both drought and salinity affect plant growth similarly through water deficit, K^+ is equally important for maintaining the turgor pressure in plants under either stress. Additionally, higher K^+, Na^+ ratios will also improve the resistance of the plant to salinity [14].

Potassium and P are both essential for photosynthesis, enzyme/energy driven reactions, seed formation and quality, stress tolerance, crop maturity, etc. Research has documented cases of P/K interactions. They illustrate the agronomic and economic benefits of eliminating P and K as limiting factors in crop production [5].

Potassium, like P, is present in relatively low concentrations in the soil solution. Potassium is readily adsorbed onto the surface of soil particles and is fixed, and thus unavailable, within layers of expandable 2:l clay minerals. Potassium (K) and sodium (Na) coexist on the soil exchange complex and soil solution. Both cations may exert antagonistic or synergistic effects on mutual absorption and translocation within plants, particularly under saline and saline-sodic field conditions [15]. Potassium uptake by plants can be affected by high salinity and the Na concentration in the soil solution. There is abundant evidence that Na and the Na/Ca ratio affects K uptake and accumulation within plant cells and organs and that salt tolerance is correlated with selectivity for K uptake over Na [7].

Salinity effects on growth and nutrient composition in four grain legumes faba bean (*Vicia faba* L.), pea (*Pisum sativum* L.), soybean (*Glycine max* L.) and common bean (*Phaseolus vulgaris* L.) and observed higher K levels in the roots than in the shoot and higher Na content in both roots and shoots [20]. High salt (NaCl) uptake competes with the uptake of other nutrient ions, especially K^+, leading to K^+deficiency [23].Potassium deficiency in plants reduced the growth rate but increased supplies of K make up for 6% of the plant dry matter.This disorder might occur by specific toxicity of ions such as Na^+ and Cl^- and might be balanced by increasing the concentration of counterions, like K^+ and Ca^{2+}, against Cl^-[29].Increased treatment of NaCl induces increase in Na^+ and Cl and decrease in Ca^{2+}, K^+, and Mg^{2+} levels in a number of plants[23].

Apart from rapidly occurring water stress, increases in ambient salt concentrations can lead to toxic accumulation of ions such as Cl^- and, in particular, Na^+ ion in the cytosol. The disproportionate presence of Na^+ in both cellular and extracellular compartments negatively impacts on the acquisition and homeostasis of essential nutrients such as K^+ and Ca^{2+}[20].

Numerous studies have shown that the K^+ concentration in plant tissue is reduced as the NaCl salinity or the Na^+/Ca^{2+} ratio in the root media is increased. Reduction in K^+ uptake in plants by Na^+ is a competitive process and occurs regardless of whether the solution is dominated by Na^+ salts of Cl^- or $S0_4^{2-}$[13].

Although salinity decreases K^+ accumulation in leaves, the increase in macronutrients that occurs at an optimal K-fertilization level does not alter the K^+ concentration for a given salinity level. At a deficient level of K^+, however, K^+ accumulation under salinity was significantly increased with an increase in the macronutrient content [14]. Under field conditions, soil solution K+ remains relatively low even after fertilizer additions of K+. Therefore, it is difficult to imagine many situations in which reasonable amounts of K+ added to the soil would completely correct Na^+-induced K^+ deficiencies in plants suffering from this disorder [13].

5. Conclusion

Soil salinity and acidity are usually accompanied by mineral toxicity, nutrient deficiency, and nutrient disorder. To improve productivity under saline conditions requires a better understanding of the rhizobia mechanism and the implications in salt stress.

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