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Salty Troubles

Understanding the Effects of Soil Salinity on Vegetable Crop Growth

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Introduction

Salinity is a significant issue that has an impact on crop productivity all over the world. 33% of irrigated land and 20% of all cultivated land are damaged and degraded by salt. Climate change, excessive groundwater usage, rising irrigation water quality consumption and widespread introduction of irrigation linked to intensive farming can all exacerbate this process. Many agricultural crops, including most vegetables, which are particularly sensitive throughout the plant's ontogeny, suffer from excessive soil salinity, which lowers their yield. Most vegetable crops have poor salt tolerance (EC_t; 1 to 2.5 dS m^{-1} in saturated soil extracts) and when saline water is used for irrigation, this salt tolerance reduces. This article's goal is to explore how salinity affects the growth of vegetables and how management techniques (such as irrigation, drainage, and fertilisation) might reduce the negative impacts of salt by preventing soil and water salinization.

The world's expanding population, along with environmental stressors like climate change, present serious obstacles to food security worldwide. Understanding the complex interactions between agriculture and the environment is crucial as we work to feed the world sustainably. This puzzle's key component is soil health, and soil salinity is one of the most urgent problems endangering agricultural yield.

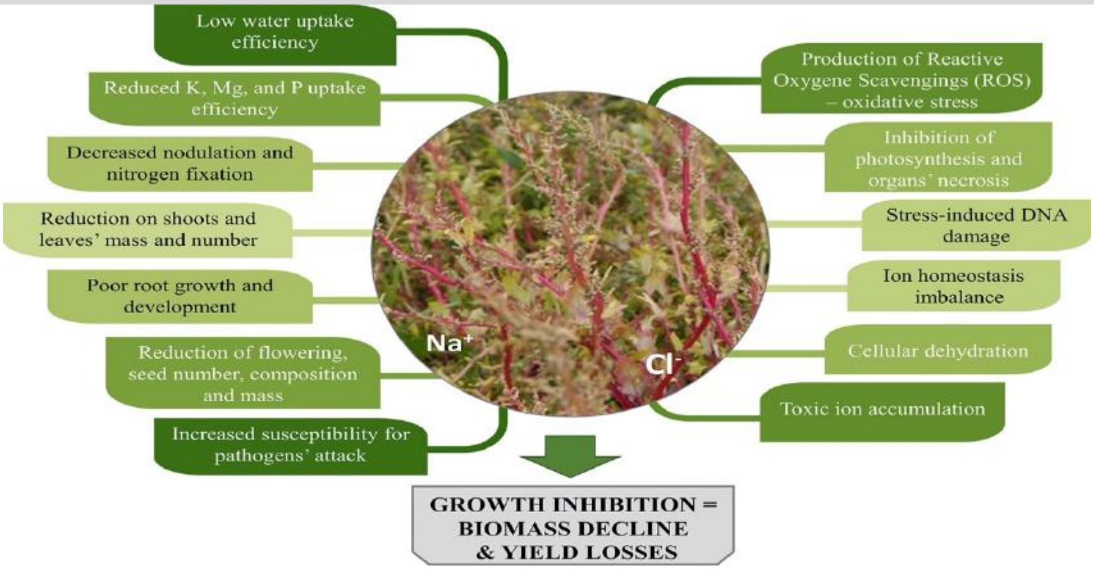
Understanding Soil Salinity

When the amount of soluble salts in the soil exceeds what plants can tolerate, the soil is said to be salinity. These soluble salts mostly consist of calcium sulphate, magnesium sulphate and sodium chloride (table salt). A soil is considered to be saline if its saturation extract conductivity is larger than 4 mmhos/cm, its exchangeable sodium percentage (ESP) is lower than 15 and its pH is lower than 8.5. Salinity can be anthropogenic, the result of human actions such irrigation practises and poor water management or naturally occuring, as observed in arid and semi-arid environments. Increases in irrigation and fertilisation practises are directly tied to increases in soil and water salinity. As a result, the goal of this review is to examine how salinity affects the growth of vegetables and how management practises (such as irrigation and fertilisation) can prevent soil and water salinization and lessen salinity's negative impacts.

Alkalization

Increased pH of the soil and high salt have a detrimental effect on the physical condition of the soil, salinity can have an indirect effect on plant growth. In typical soils with some organic matter content, exchangeable cations like Ca^{2+} and Mg^{2+} link clay particles to humic acids, forming stable micro-aggregates that form the basis for soil structure, porosity, and internal drainage. In soils with high sodium concentrations, calcium and magnesium adsorbed on the soil exchange complex are replaced by sodium, which has little flocculating ability, causing the soil particles to scatter. Damage to soil structure is accompanied by an increase in soil compaction as well as reductions in infiltration, hydraulic conductivity, and oxygen availability in the root zone. Another effect of a high salt content is a rise in pH (alkalization), which is caused by the presence of HCO_3^- and CO_3^{2-}. A linear relationship exists between the exchangeable sodium percentage (ESP) and soil pH. A surplus of sodium (Na^+) in the soil prevents crops from accessing Ca^{2+}, K^+, and other cations. Because of this, soils with high exchangeable sodium (Na^+) levels may be harmful to plants that are sensitive to salt as well as having low or imbalanced nutrient levels and soil particle dispersion.

Effects of salinity on Vegetable Growth and Nutrition



Stunted Growth

Stunted growth is one of the most obvious effects of soil salinity on vegetable crops. High salt levels in the soil prevent root growth, which lowers water and nutrient uptake. Because of this, plants experience restricted growth, which is seen as lesser plant height, smaller leaves, and generally smaller stature.

Altered Fruit Quality

Vegetable crop quality can be severely impacted by soil salinity in addition to crop quantity. Inevitable characteristics like increased bitterness and changed flavour are frequently seen in vegetables cultivated under saltwater circumstances. Vegetables may become unappealing and unmarketable due to the produce's weakened texture. Additionally, vegetables' nutritional quality may suffer due to lower concentrations of vital vitamins and minerals, diminishing their utility as a food source.

Nutritional Deficiencies

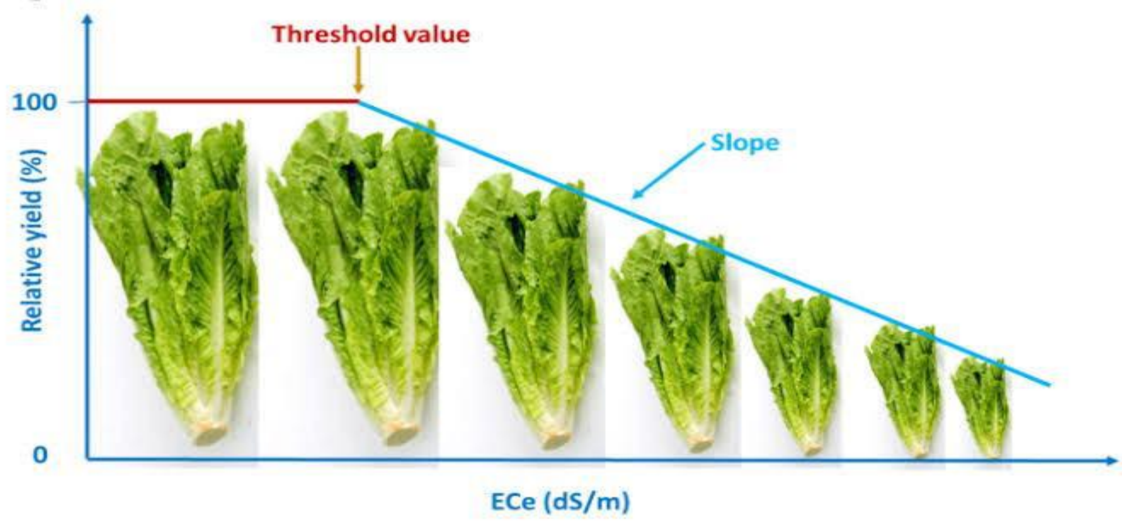
Salinity in the soil prevents the absorption of vital nutrients, which causes nutritional imbalances in vegetable crops. For uptake by plant roots, sodium ions (Na^+) compete with other cations such potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}). Consequently, the excessive accumulation of sodium ions in plant tissues can impede the absorption of these critical nutrients, resulting to deficits that hinder overall plant health and growth.

Impaired Photosynthesis

Photosynthesis, the fundamental mechanism through which plants turn sunlight into energy and create carbohydrates, is adversely impacted by soil salt. The plant's capacity to efficiently catch light energy and carry out photosynthesis is hampered by the lower supply of water and nutrients brought on by salt stress. Therefore, under salt conditions, vegetable crops exhibit lower rates of photosynthesis, which results in poorer biomass production and ultimately lower yields.

Yield Reduction

Crop yields can be significantly reduced when soil salt causes stress during critical growth stages, such as flowering and fruit development. Reduced fruit size, fewer fruits per plant, and overall decreased productivity are some of the factors that have a detrimental effect on yield. Vegetable crop production losses are attributed to all of these variables.



Increased Susceptibility to Pests and Diseases

Stressed plants are more vulnerable to disease and pest infestations because they are working harder to overcome problems brought on by salt. Plant defences are weakened by soil salt, rendering them more vulnerable to different diseases and pests. Crop losses in vegetable cultivation are made worse by this increased vulnerability.

Imbalanced Water Relations

An osmotic gradient caused by high salt concentrations in the soil prevents plant roots from effectively absorbing water. Reduced turgor pressure, wilting, and general water stress are the results of the plant's decreased water availability. Inadequate water relations make it difficult for the plant to maintain healthy cell turgidity, which affects photosynthesis, transpiration, and nutrient delivery.

Vegetable Tolerance to Salinity

The ability of a plant to survive the effects of excessive salt concentrations in the root zone or on the plant's leaves without suffering a substantial negative effect is sometimes referred to as salt tolerance or resistance in plants.

According to measurements made by Maas and Hoffman in 1977 and van Genuchten and Hoffman in 1984, salt tolerance is defined as a complicated function of yield decline over a range of salt concentrations. Two parameters—the threshold (ECt), the electrical conductivity predicted to initially significantly reduce the maximum projected yield (Ymax), and the slope (s)—can be used to accurately quantify salt tolerance. Slope is only the proportion of yield that will be reduced for each additional unit of salinity above the threshold value. Relative yield (*Y*) at any salinity exceeding EC_t can be calculated:

$Y = 100 - s(EC_e - EC_t)$

The salt tolerance threshold for crops, or the salt concentration at which production first starts to decrease with increasing concentration, is extremely susceptible to environmental influences. The salinity threshold for the majority of vegetable crops is 2.5 dS m1. A typical finding regarding salt sensitivity of plants in relation to growth stage is that plants in their early growth phases (seedling, establishment) are more sensitive to salt stress than plants in their later growth stages. The percentage of survival is used to determine tolerance during germination and emergence, while relative growth reductions are typically used to quantify tolerance during the later developmental stages. When applied during the first growth phase, salinity primarily had an impact on cauliflower growth. Salt tolerance is also impacted by the EC of irrigation water. The lowest irrigation water threshold level, ECw, that did not limit crop growth was 0.7 dS m1, which was lower than ECe (1 dS m1). Most vegetable crops have a low tolerance for continuously applied saline water. Sensitive, moderately sensitive, tolerant, tolerant, and inappropriate for crops are the different categories of salt tolerance. Most vegetable crops are either highly sensitive or moderately sensitive. The vegetable crop with the highest salt tolerance is thought to be asparagus.

Management Practices

Soil Reclamation: The introduction of amendments to improve soil permeability and lower the exchangeable sodium levels may be necessary for the reclamation of sodic soils in addition to leaching. Sodic soil rehabilitation is replacing the sodium ions in the soil with calcium ions by adding a lot of gypsum (CaSO4). The extra water is then used to leach the released sodium ions far beyond the root zone, and the field's drainage is used to transport them away. Gypsum releases calcium ions when it is gently combined with water. These calcium ions replace sodium ions from the soil in the water's downward motion. Elemental sulphur (S0), which is converted to sulfuric acid by soil bacteria (S0 + 12O2 + CO2 + 2H2O H2SO4 + CH2O), can also be used as an alternative to gypsum. Because sulphur oxidation depends on soil temperature, humidity, aeration, and other factors, the impact of a S0 amendment might be slower. Due to an increase in H3O+ in soil solution, sulfuric acid and elemental sulphur addition also cause a decrease in soil pH.

Fertilization: One of the causes of salinized soils is crop fertilisation. Consideration must be given to fertiliser properties, fertiliser application techniques, irrigation water quality, fertilisation schedules, etc. in order to lessen this adverse effect. High-purity, chloride-free, low-saline fertilisers should be chosen instead of excessive nutrient applications. Vegetable crops grown with irrigation need to have their nutritional needs met by the soil, fertilisation, and irrigation water's nutrient content. High nutrient concentrations in irrigation waters, such as nitrate-N, calcium, magnesium, sulphur, and boron, may be adequate to partially or entirely meet crop needs. Fertigation, which involves applying fertilisers through irrigation water, increases the availability of nutrients and the timing of application while allowing for easy control of fertiliser concentration, all of which help to reduce soil salinization and mitigate the effects of salt stress. In order to match nutrient supply to plant needs, fertilisation enables frequent applications of relatively low fertiliser rates.

By promoting root growth, changing mineral uptake, and reducing membrane damage, humic compounds can mitigate the negative effects of salt stress and promote salt tolerance. Humic acids were added to the saline medium to increase the salt tolerance of certain crops. Humic acid treatments improved the K^+/Na^+ and Ca^{2+}/Na^+ ratios in pepper.

Additionally, the application of biofertilizers can lessen soil salinization and the impacts of salinity on vegetables. A prepared product containing one or more microorganisms that improves the nutrient status (and the growth and productivity of the plants) by either substituting soil nutrients, improving the availability of nutrients to plants, or enhancing plant access to nutrients is referred to as a biofertilizer. Nutrient intake, plant growth, and salt stress tolerance were all enhanced by the application of plant growth-promoting rhizobacteria (PGPRs), endo- and ectomycorrhizal fungi, and numerous other beneficial microscopic organisms. Increased root and branch development, dry weight, fruit, and seed yield, as well as improved plant resistance to salt stress, can be obtained by inoculating seeds of several crop plants with PGPRs, including tomato, pepper, bean, lettuce, and others.

Irrigation: Water-use efficiency (WUE), nutrient-use efficiency, salt accumulation and distribution, and salt leaching can all be influenced by irrigation method, management (irrigation timing and leaching fraction), and artificial drainage. Irrigation techniques include surface drip irrigation (DI) and subsurface drip irrigation (SDI), furrow irrigation, and low energy precision application (LEPA) irrigation must be employed if foliar damage caused by salts in irrigation water is a concern. By improving water and nutrient use efficiency, DI and SDI allow for improved salinity management as compared to conventional irrigation techniques. To make sure that the zones of salt accumulation stay away from germination seeds and plant roots, tactics like manipulating bed design and planting arrangements are frequently employed. Salts are typically moved below the root zone by sprinkler irrigation and a suitable leaching proportion. However, crops may be prone to further harm from salt absorption into the leaves and burn from spray contact with the foliage when saline water is utilised for irrigation. The severity of the damage varies with the weather; in hot, dry circumstances, it is most severe because evaporation concentrates the salts at the leaf surface. Saline water sprinkler irrigation must therefore be carried out when it is the coolest outside. The irrigation schedule may incorporate deficit irrigation tactics when irrigation water is limited, as when a drought occurs. Deficit irrigation (DI) is an optimisation technique in which less water is applied than what the crop actually needs to evapotranspire.

Maintenance leaching: It is essential to do a maintenance leaching in order to ensure the long-term use of the land with irrigated vegetable crops. In addition to the volume of water required for regular irrigation, irrigation must also apply a quantity of water that drains down the root zone. The leaching fraction (LF) is the term used to describe this excess water. To ensure successful irrigation over the long run, leaching is a must. Typically, an LF of 15 to 20% is advised. The amount of salinization, evaporative requirement, and salt sensitivity of the crops all affect how often leaching is necessary. Each irrigation event in arid areas must incorporate LF. When drip irrigation is employed, leaching may occur everyday for a month or twice or three times per week for moderately sensitive and sensitive crops, respectively.

Future Outlook

The issue of soil salinity in vegetable crop production is not going away anytime soon, and it is likely to become even more critical in the face of climate change. Rising temperatures and changing precipitation patterns can exacerbate salinity problems by increasing evaporation rates and altering the distribution of salts in the soil.

However, there is hope on the horizon. Advances in plant breeding and biotechnology are paving the way for the development of highly salt-tolerant vegetable varieties. Additionally, sustainable agricultural practices, such as organic farming and no-till agriculture, can enhance soil health and reduce the impacts of salinity.

Conclusion

Soil salinity poses significant challenges to vegetable crop growth and production. However, by understanding the effects of soil salinity and implementing appropriate management strategies, farmers can mitigate these issues. Adequate soil drainage, efficient irrigation practices, amendments, and crop selection play crucial roles in sustaining vegetable crop growth in saline soils. As we navigate the path towards feeding a growing global population while preserving our natural resources, understanding and mitigating the impacts of salinity on agriculture will be a crucial step forward. Through innovative research, sustainable practices, and a commitment to the resilience of our food systems, we can address the salty troubles that threaten vegetable crop production and secure a more food-secure future. Continuous research and technological advancements are necessary to develop improved salt-tolerant varieties and innovative management practices to ensure food security and sustainable agriculture in salt-affected regions.

References

1. Machado, R.M.A. and Serralheiro, R.P., 2017. Soil salinity: effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. *Horticulturae*, *3*(2), p.30.
2. De Pascale, S. and Barbieri, G., 1995. Effects of soil salinity from long-term irrigation with saline-sodic water on yield and quality of winter vegetable crops. *Scientia Horticulturae*, *64*(3), pp.145-157.
3. Bresler, E. and Hoffman, G.J., 1986. Irrigation management for soil salinity control: theories and tests. *Soil Science Society of America Journal*, *50*(6), pp.1552-1560.
4. Mukhopadhyay, R., Sarkar, B., Jat, H.S., Sharma, P.C. and Bolan, N.S., 2021. Soil salinity under climate change: Challenges for sustainable agriculture and food security. *Journal of Environmental Management*, *280*, p.111736.