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Effect of Salinity and Sodicity on Vegetable Production and Remedial Measures: A Review

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Authors' contributions

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Review Article

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ABSTRACT

The word salinity comes from the Latin word *salinium* which means "salt cellar" and it means "position or quality of being". Sodicity indicates the amount of sodium converted to calcium and magnesium in soil. High sodicity suppresses plant growth due to sodium toxicity and nutrient imbalance in plants, as well as low availability of mineral nutrients in the soil. Salt stress is the cause of the slow growth and growth of plants and leads to changes in yield and quality in a variety of crops. Plants provide a complex response to salt and changes in the morphology, physiology and metabolism of plants are observed. The effect of salt on various vegetable plants namely beetroot, cabbage, capsicum, kabuli chana, coriander, fenugreek, lettuce, onion, tomato, potato was reviewed. Salinity was adversely damaged as a result of salinity: Seed formation, survival percent, phonological attribute, growth and yield, its components, dry and fresh weight were affected. Photosynthesis and respiratory rates of plants were reduced. Salinity reduced total carbohydrate, fatty acid, and protein content but notably increased amino acid levels. The growth of asparagus and tomatoes was more concentrated in sodic soils than saline soils, indicating that asparagus and tomatoes are sensitive to sodicity. Beans also die in sodic soils, indicating that the beans are very sensitive to sodicity. The negative effects of alkaline water on the addition of gypsum and FYM have shown a significant increase in plant growth and yield limits.

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1. INTRODUCTION

Salt is dissolved in water. It may also refer to soil salts. Saline soils are defined as high soluble salts, sufficient to affect plant growth. Salt comes from natural or man-made processes that lead to the accumulation of dissolved salt in groundwater in a way that inhibits plant growth. Sodicity is the second source of salinity in clay soils, where the flow of natural or man-made processes washes away the soluble salts in the subsoil, and binds sodium to poor soil drainage. Salt in a particular part of the country depends on a variety of factors such as the amount of evaporation that increases the salt concentration and the amount of precipitation that decreases the salt. Irregular irrigation, inadequate drainage, incorrect fertilizer application can result in salinity and it is especially high in protected farming. The problem of salinity arises due to accumulation of soluble salt in the root zone. These high salts reduce plant growth and energy by altering water absorption and causing certain ion toxicity or imbalance. Installing plumbing is often the solution to these problems, but salt problems are often complex. To increase the productivity of salt affected soils, proper management practices along with periodic soil testing are required. The term salinity is derived from the Latin word *salinium* which means "salt cellar" and it means "position or quality of being". Salt refers to the presence of salt dissolved in soil or water. Tolerance of plant salts or resistance to the natural strength of the plant, to combat the effects of excess salt in the root zone or leaves of the plant without significant adverse effect [1]. The addition of salt to the soil is a major factor contributing to the production failure of the cultivated soil. Although difficult to estimate accurately, the salinity of the soil is increasing and the situation is particularly critical for irrigated soils. It is estimated that 20% (45 million hectares) of irrigated land, which produces one third of the world's food, is affected by salt [2]. This rate is accelerated by climate change, excessive groundwater consumption, increased low water use in irrigation and the introduction of large-scale irrigation associated with robust agriculture and poor water flow. On the other hand, the tendency to increase the efficiency of irrigation water, as guaranteed in many areas due to water shortages and low water consumption can lead to salt accumulation in the soil, as the leaching fraction decreases. and the salt contained in the irrigation water is not sufficiently hot. It is estimated that by 2050, 50% of arable land will be affected by salt [3]. Amassing of overabundance salt in the root zone brings about the incomplete/complete loss of soil profitability worldwide. The salinity problem of the soil is widespread in arid and semi-arid areas, but salt-affected soils occur mainly in moist and humid areas, especially in coastal areas through estuaries and rivers and seawater that enters the groundwater table, resulting in significant salinity. Soil salinity is also a major problem in areas where high ground salt water is used for irrigation. This is a major challenge for crops that hinder agriculture around the world, especially in irrigated fields [4]. Exorbitant soil saltiness diminishes the profitability of numerous horticultural harvests, including very soft vegetables at the entrance to the plant. Plant sensitivity to salt stress is manifested in loss of turgor, reduced growth, shrinking, leaf folding and epinasty, leaf removal, decreased photosynthesis, respiratory changes, loss of cellular integrity, tissue necrosis, and plant death [5,6]. Salty soils are generally defined as those where the electrical conductivity of the extract saturation (ECE) in the root zone exceeds 4 dS m-1 (approximately 40 mM Nacl) at 25 dC and contains 15% volatile sodium. At ECE, the yield of most crop plants decreases, although most crops show a decrease in yield at lower ECs [7,8]. Soil salinization causes soil erosion on a global scale and reduces crop productivity [9]. Because most vegetable crops are glycophytes in nature, salt stress is one of the most cruel environmental factors limiting vegetable crop productivity. Because vegetables have a high monetary value, salt tolerance is essential. Salinity affects one-third of the world's irrigated land [10]. Different environmental pressures namely. high winds, high temperatures, soil salts, droughts and floods affect the production and cultivation of agricultural crops, this soil salt is one of the most destructive environmental pressures in the uncultivated area, crop production and quality cause deficit. [11,12]. The urgency of feeding the world's growing population while tackling pollution, immersion of salt, and desertification has given impetus to plant and soil production research. In such cases, it requires not only the appropriate biotechnology tools to improve plant production, but also to improve soil health through the close interaction of plant roots and soil microorganisms [13]. Microorganisms can play an important role in this if we take advantage of their unique characteristics such as salt tolerance, genetic diversity, coagulation of compatible solutes, growth hormone growth hormone, the ability to control bio and their interactions with plant extracts. Ensuring adequate food production is a major problem in the context of population growth. In order to reduce the area of irrigation land, salt salts are often the main cause of poor irrigation techniques. To increase food security, there is a need to build salt-resistant plants, which can grow successfully in salt-affected countries. In plants, vegetables occupy an important place in the human diet because its nutrients provide vitamins, minerals, fiber and anti-oxidants etc. Salt is involved in every aspect of the development of the vegetable harvesting process, including its growth, vitality and yield. The development of salt-tolerant farming often requires the transfer of more genes due to more plant-resistant strains or to tolerate this abiotic stress [14]. In general, vegetables have a high economic value per unit of plants used and field crops. This can be of great benefit to smallholder farmers, as vegetables can be grown in small areas, under strict procedures. Vegetable crops usually need more water and irrigation more often than other agricultural crops. The creation of vegetable crops in arid and low rainfall areas and high temperatures requires a significant contribution of compost and water system. However, the increase in soil salts and water is closely related to irrigation and fertilization processes [1]. Ground salt is known to inhibit plant growth [15]. Endocellular and intracellular microorganisms colonise plants in their natural environment [16]. Rhizosphere microorganisms, particularly beneficial bacteria and fungi, can improve plant performance under stress conditions and, as a result, increase yield both directly and indirectly [17]. Rhizobacteria (PGPR) that promote plant growth can provide plants with a direct stimulus on growth and development, providing plants with fixed nitrogen, phytohormones, iron sequestered by the bacteria siderophores, and soluble phosphates [18]. Others indirectly protect the plant from soil-borne diseases, the majority of which are caused by pathogenic fungi [19]. Salt is found naturally in the soil, in surface water, and in groundwater systems. The most common salt that produces salt is sodium chloride, but it may contain salts such as magnesium, calcium, or potassium. Soluble salt has less sodic acid but is much higher in volatile sodium. Sodic soils are not suitable for most plants due to high sodium concentrations, which can cause plant roots to deteriorate, and due to their high pH, which usually ranges from 8.5 to 12.0. These high sodium levels interfere with the chemical composition and composition of the soil. As a result, the surface of the soil can absorb air, rain and irrigation water. The soil is sticky when wet, but solid flakes and crusts form when dried. This condition cannot occur in sandy soils because it has no soil content [20]. Any impact on plants that inhibits their ability to grow and develop is referred to as abiotic stress. Crop output is reduced by 69 percent as a result of abiotic stress. Drought, excessive temperatures, and high soil salinity are the main abiotic stress [21]. In dry and semi-arid areas, over 950 million hectares of land are influenced by natural and manmade factors [22]. Plants can be split into two categories based on their adaptive development: halophytes (plants that can survive under salt stress) and glycophytes (plants that cannot survive under salt stress) [23]. At the cellular, tissue, and entire plant levels, halophytes respond to salinity [24]. Halophytes have the best genetics for surviving in saline environments and can even thrive in acute salt stress [25]. Many parts of the world have soil that is too salty for profitable crops, causing oxidative stress and osmotic impacts on plant growth [26]. High salinity levels in productive agricultural land are the most serious problem for agricultural crops. Saline soil affects about 10% of the land surface and 50% of irrigated land, according to estimates. Plants respond to salt in a complicated way, including changes in their morphology, physiology, and metabolism. Plants suffer from cellular water loss, ion toxicity, nutritional shortage, and oxidative stress as a result of salinity, which causes growth, molecular damage, and plant mortality. Due to salt-affected soil, there is a global annual loss in agricultural production of around $ 10 billion [27]. As a result of poor management of natural resources, salinity is becoming a big problem. Because harmful ions present in the soil, salinity causes water and ionic imbalances in plants. Salt stress causes the plant to grow and the leaf colour to darken [28]. Plants respond to salt stress in two ways: one is osmotic, which slows the growth of young leaves, and the other is ionic, which hastens the senescence of mature leaves [29]. It also decreases the photosynthetic and respiration rates of plants in general. Salinity has an impact on total carbohydrate, protein content, and fatty acids, but it also aids in increasing amino acid levels, particularly timeline levels. Plants cultivated under salt stress produce more secondary plant products than crops grown in natural conditions, according to common observation. Plants' salinity tolerance is determined by the interaction of salt and the surrounding environment. Plant productivity is influenced by salinity, especially in dry and semi-arid areas. The negative effects of salt stress can be divided into three categories: (1) The first type causes water stress in plants by lowering the osmolarity of the soil solution (2) the second group, in which the degradation of the physical structure of the soil prevents soil aeration and water permeability, and (3) the third group, in which the concentration of particular ions is increased, inhibiting plant metabolism and mineral nutrient imbalance [30]. Saline soils are also affected by high sulphate, carbonate, and bicarbonate concentrations. Poor soil structure and aeration are also contributing factors [31]. At low quantities, salinity reduces the germination rate, but at high concentrations, it increases the germination percentage. This impact could be caused by anaerobic conditions in the root membrane, which cause active transport and exclusion mechanisms to fail. Single salt solutions have varying effects on germination, but mixed salt solutions respond more consistently and are mostly influenced by osmotic potential. The effects of salinity on development time are common. When onions are exposed to salt, they flower quicker, yet salinity causes tomatoes to flower later. Differential responses to salinity stress can also be shown in the yield component and growth characteristics. Root growth is often less influenced, or even stimulated, by saltwater growth in low salinity than shoot growth. Turnip growth underground [32] and carrot [33] Salinity sensitivity was greater than that of root development. The output of asparagus spears was less impacted by salinity than that of ferns [34] and Artichoke bud growth was hindered by salt more than shoot growth [35]. As a result of smaller leaves, shorter stature, and sometimes fewer leaves, salt has a general influence on growth pace. The osmotic effects of salinity, especially at low to moderate concentrations, are the initial and predominant effect [36]. Salinity does not always have to be a bad thing; it can have positive benefits on yield, quality, and disease resistance. For example, yields in spinach may initially increase from low to moderate salinity [37]. As salinity rises, the sugar content of carrots rises and the starch content of potatoes falls [38], When salinity is low, cabbage heads are more firm, but as salinity rises, they become less compact [39]. Celery has been reported to be more resistant to blackheart and more sensitive to it [40]. Plants are unable to collect as much water from the soil when the soil grows more saline. This is due to fluctuating concentrations of ions (salts) in the plant's roots, which provide a natural flow of water from the soil to the plant's roots. As the saline level in the soil approaches the roots, the amount of water in the soil falls, and the likelihood of water entering the roots diminishes. When the earth's salinity is high enough, the water in the roots is actually pulled back into the soil. Plants can no longer absorb enough water to grow. The levels of root salts in each plant species vary naturally. This is why certain plants thrive even after they have died. Regardless of how much water is applied, if the salt concentration in the soil is high enough, the plant will wilt and die [20]. The bulk of vegetable crops have a low tolerance for saltwater that is regularly seeded. Sensitive, moderately sensitive, moderately tolerant, tolerant, and inappropriate for crops are the salt tolerance grades. The majority of vegetable crops are sensitive or somewhat sensitive to pesticides [41,42]. Asparagus has long been thought to be the most salt-tolerant vegetable [43].

1.1 Soil Salinity Problem

Soil salinity is a major issue in irrigated agriculture. Saline soils are common in hot and arid places of the world with little agricultural potential. The majority of the crops farmed in these areas are irrigated, and to make matters worse, poor irrigation management causes secondary salinization, which affects 20% of irrigated land worldwide [44]. In arid and semi-arid areas, irrigated agriculture is a major human activity that frequently results in secondary salinization of land and water supplies. Soil salts are in the form of ions (electrically charged forms of atoms or compounds). Ions are released when minerals in the soil weather. They can also be applied as fertilisers or by irrigation water, and they can flow upstream from shallow groundwater into the soil. Soil salts accumulate when rainfall is insufficient to remove ions from the soil profile, resulting in soil salinity [45]. Water-soluble salts are found in all soils. Essential nutrients are absorbed by plants in the form of soluble salts, but excessive accumulation inhibits plant growth. Physical, chemical, and/or biological land degradation processes have had major effects for global natural resources over the last century (for example, compaction, inorganic/organic contamination, and low microbial activity/diversity). Due to the installation of irrigation in new places, the area of affected soil continues to grow every year [46].

Salinization is widely recognised as one of the most serious threats to environmental resources and human health in many countries, affecting roughly 1 billion hectares worldwide/globally, or about 7% of the Earth's continental range, or roughly 10 times the size of Venezuela or 20 times the size of France [47,48]. Saline soil covers around 7 million hectares of land in India, according to estimates [46]. The Indogenetic Plain, which includes the desert states of Gujarat and Rajasthan, as well as the semi-arid states of Gujarat, Madhya Pradesh, Maharashtra, Karnataka, and Andhra Pradesh, is largely influenced by saline terrain [2].

1.2 Methodology

According to the following equation, the ESP was calculated using the Sodium Adsorption Ratio (SAR).

$$ESP = [100\ (-0.0579 + 0.0155 \times SAR)] / [1 + (-0.0579 + 0.0155 \times SAR)]$$

$$SAR = Na^{+} / \{(Ca + Mg) / 2\}^{1/2}$$ [49]

2. SALINITY'S CAUSES

2.1 Primary Cause

Natural geological, hydrological, and pedoliprocesses generate saline soils that contain igneous rocks, volcanic rocks, sandstones, alluvial, and lagoonal deposits. In dry and semi-arid locations, evapo-transpiration is crucial in the production of saline soil. Coastal locations, irregular water incursions, and rivers are the main sources of salinity [30].

2.2 Secondary Cause

Human-affected soils are included in this category. Humans refers to a poor irrigation system or water quality used to irrigate crops, resulting in soil salinity. In dry and semi-arid environments, water logging caused by inappropriate irrigation leads to anthropogenic. The second reason for soil salinitation is inappropriate irrigation.

(1) The main cause of salinity and alkalinity is deforestation, which allows salt to re-settle in upper and lower levels.
(2) Salts that are disseminated industrially and wastewater that are airborne and waterborne, respectively.
(3) Chemical pollution can also result in salinization, which is more common in current agricultural systems, particularly intensive farming and greenhouses.
(4) Overgrazing, which is common in arid and semi-arid areas, is another reason [30].

Table 1. Soil salinity tolerance is used to classify vegetable crops

Less tolerant	Moderately tolerant	Highly tolerant
➢ Pea ➢ Radish ➢ Snake Gourd ➢ Beans ➢ Brinjal ➢ Sweet Pepper ➢ Potato ➢ Sweet potato	➢ Tomato ➢ Chilli ➢ Watermelon ➢ Cucumber ➢ Summer squash ➢ Bottle gourd ➢ Cabbage ➢ Cauliflower ➢ Broccoli ➢ Muskmelon ➢ Onion	➢ Asparagus ➢ Beet ➢ Kale ➢ Turnip ➢ Bitter gourd ➢ Ash gourd ➢ Palak ➢ Lettuce

[20]

Table 2. Salt-affected soils

Type	EC(Ds/m)	pH	SAR	ESP
Saline	>4	<8.5	<13	<15
Sodic	<4	>8.5	>13	>15
Saline-Sodic	>4	<8.5	>13	>15

[50]

2.3 Salt Stress Tolerance of Plants

According to the United Nations Environment Program, salinity affects about 20% of agricultural land and 50% of crop land around the world. The salt stress condition of the land limits the amount of calories and nutrients available for agricultural development. These restrictions are most typically encountered in places where there is a lack of basic infrastructure for food distribution. Biotechnology relies heavily on genetic determinants of salt tolerance and yield stability. Significant study efforts must be devoted to determining salt tolerance and the impacts of components that govern instructions during stressful situations. Additional resource material that demonstrates how plants become aware of salt stress, how they resist against it, and how they achieve stable development in a saline environment. High salinity is caused by hyperosmotic stress and ion imbalance, which has a secondary consequence. Plants, in general, withstand or avoid salt stress, which means that they are in during salt stress or the resting phase of the cells will adjust to saline circumstances. Tolerance is divided into two categories: those used to minimise osmotic stress, those used to prevent ion imbalance, and those used to mitigate the secondary effects of these stresses. First, a water potential imbalance between apoplast and symplast is generated by the chemical potential of saline solution, which causes turgor to be lowered, resulting in a decrease in growth [51]. Plant survival in harsh environments Stress adaptive metabolism and structural alterations must be integrated [52].

2.4 Salinity's Effects on Vegetable Crops

Because salinity causes both, salinity symptoms (salt stress) can resemble both water stress and nutrient deficiencies. Leaf margins usually turn yellow and die as a result of salts accumulating due to transpiration. As a result, the symptoms resemble those of potassium shortage. Plants are smaller and may die off sooner than expected. Seedlings have a hard time establishing themselves. Testing the soil, water, and plant sap is the best approach to determine salt stress [53].

2.4.1 Sodic soils

Sodicity refers to the ratio of transferable Sodium to Calcium and Mg in soil, and excessive sodicity inhibits plant growth owing to Na toxicity and nutrient imbalance in plants, as well as insufficient mineral nutrient availability in the soil [54]. Sodic soils are formed by negatively charged sites on soil particles for adsorption of sodium ions, usually clay solutions, salts liberated from soil solutions [55]. Sodic soils are the most common problem in the world's irrigated desert and semi-arid regions. In addition, the presence of interchangeable sodium, soluble sodium carbonates, and bicarbonates in irrigation water has a negative impact on rising salinity/alkalinity in these locations' agricultural lands [56]. The severity of negative impacts is determined by salt type and amount, soil texture, crop type, variety, developmental stage, cultural practises, and environmental factors (temperature, relative humidity, and rainfall) [57,58]. Sodicity is a severe problem in eleven states across the country. In Uttar Pradesh, the biggest area (1.35 million ha) is covered by sodic soil, accounting for nearly 36% of the total area. Gujarat (14.36 percent), Maharashtra (11.21 percent), Tamil Nadu (9.41 percent), Haryana (4.86 percent), and Punjab (4.02 percent) are the states with the highest levels of sodicity, accounting for about 80% of India's total sodic lands. Sodic soils reduced asparagus and tomato development more than saline soils, demonstrating that asparagus and tomato are susceptible to sodicity. The bean died in sodic soils as well, demonstrating that it was highly susceptible to sodicity [49].

2.4.2 Effects of sodicity

Soil sodicity can lead to:

- Reduced water flow through the soil - which limits leaching and can accumulate salt over time and cause salt water development.
- Dispersion in the soil surface, leading to crusting and sealing, which then prevents water infiltration.
- Spreading in the subsoil, accelerating corrosion, which can lead to the presence of lanes and tunnels
- It destroys aggregation in the form of dense, dense and structure-free soil.

2.4.3 Indicators of sodicity

Outside the field, soil hardness can be predicted in the following ways.

- Poor plant growth is less than normal, there are only a few heavy plants, or many plants or trees standing.

- Plants of different heights
- Infiltration of poor rainfall - overhead
- Rainwater spraying work - trimming and landscaping (solid setting)
- Pools with variable or green water
- Plants are shallow.
- Due to the complex growth of Na-humic, the soil is usually darker in the shade.
- Cultivation requires a lot of energy (especially in well-drained good soil)
- Immersion from the study area is difficult due to the closure of the mud channel [59].

2.4.4 Effect of alkalinity on vegetables

Like salinity, wide genetic diversity exists between plants and their species in terms of their tolerance and alkalinity. Crop yields aren't usually affected until the salt concentration and ESP in the soil solution surpass the specified values for each crop. Salt and no tolerance of winter crops are generally higher than those grown during the hot season. It is therefore suggested that (<400 mm) vegetable crops can be grown during the winter season (low ET) in areas with low rainfall, which fall under the arable crop during summer. The efficient strategy should choose crops that require less water for *rabi* and rainfed crops for *kharif* [60].

2.5 Impacts on Vegetable Growth and Nutrition

Plant growth is hampered by salts, which increase the soil's osmotic pressure and interfere with plant nourishment. The osmotic or water-deficit effects of salinity are caused by a high salt content in the

Table 3. Tolerance of vegetables to alkalinity

Sensitive Crops (ESP<20)	Semi-tolerant (ESP 20-40)	Tolerant Crops (ESP > 40)
Ginger, Turmeric, Pea, Cowpea and Cluster bean	Tomato, Garlic, Bhindi, Radish, Carrot, Cauliflower, Chilli, Onion, Potatoes, Ash gourd, Coriander, Fenugreek and Fennal	Brinjal, spinach and sugar beet

[60]

Table 4. Crop varieties tolerant to alkalinity

Crops	Varieties
Tomato	Angurlata, Azad T2
Spinach	K Hari Chikari
Garlic	Gattar gola, Hansa
Chillies	Jawala, Chaman

[60]

Table 5. Potential reduction in yield from saline soils of selected plants

	Decreased yield related (%)			
	100	90	75	50
Vegetables	($EC_{e\ ds/m}$)			
Beans	1.0	1.5	2.3	3.6
Broccoli	2.8	4.9	5.5	8.2
Cucumber	2.5	3.3	4.4	6.3
Cantaloupe	2.2	3.6	5.7	9.1
Spinach	2.0	3.3	5.3	8.6
Tomato	2.5	3.5	5.0	7.6
Celery	1.8	3.4	5.8	9.9
Pepper	1.5	2.2	3.3	5.1
Radish	1.2	1.5	2.3	3.6
Cabbage	1.8	2.8	4.4	7.0
Potato	1.7	2.5	3.8	5.9
Lettuce	1.3	2.1	3.2	5.1
Onion	1.2	1.8	2.8	4.3
Carrot	1.0	1.7	2.8	4.6

[61,62]

Table 6. Initial salinity (dS/m) at which yields begin to drop, and percent yield increase in Salinity

The name of the plant	Soil salt where the first harvest begins	Decreased yield per unit permeability salinity
Bean	.0	19.0
Broad bean	.6	9.6
Broccoli	2.8	9.2
Cabbage	0.8	6.2
Carrot	0	14.0
Celery	0.8	6.2
Cucumber	2.5	13.0
Lettuce	1.3	13.0
Onion	1.2	16.0
Pepper	1.5	14.0
Potato	1.7	12.0
Radish	1.2	13.0
Spinach	2.0	7.6
Sweet Corn	1.7	12.0
Squash	3.2	16.0
Tomato	2.5	9.9
Turnip	0.9	9.0

Source: Technical Bulletin-1, Hisar Agricultural University (SRDI,2013)

Table 7. Salt tolerance induction in some vegetable crops

Plant name	Chemical name/growth factor	Concentration	Process of treatment	Treatment duration (Hr.)
Cauliflower	CCC	250 ppm	Immersion of artificial roots	2.0
Okra	CCC	500 ppm	Seed Soaking	6.0
Onion	CCC	1.0 %	Root Dipping for Transplanting	8.0
Potato	Sodium Salt Solution or CCC	6.0 dS/m EC or 250ppm	Tuber Soaking	2.0
Tomato	Sodium Salt Solution	8.0 dS/m EC	Root Dipping for Transplanting	2.0

Source: Technical Bulletin-1, Hisar Agricultural Universit. (SRDI, 2013)

soil solution, which decreases the ability of plants to receive water. When concentrations reach a point where they inhibit crop growth, losses occur. The osmotic effect of salinity causes metabolic changes in the plant, which are accompanied with wilting [63] and some genetic differences [64]. Salt stress also inhibits plant growth due to specific-ion toxicity and nutritional imbalance [64], or a combination of these variables [64], [29]. Indeed, the effect of salinity on plant growth is a time-dependent process, and [65] established a two-stage model to describe the salinity response of plant growth. The first phase is quite fast, then the development slows down to accommodate the growth of water scarcity. Poisoning occurs in the second phase due to the accumulation of salts in the shoot and is very sluggish. Despite the fact that broccoli has been featured in this model [66] the related significance of the two methods of crop reduction is difficult to assess with confidence because they are compatible. Salt affects photosynthesis due to reduced availability of CO_2 as a result of distribution limits [67] and lack of photosynthetic pigment content [68,69]. The accumulation of salt in spinach inhibits photosynthesis [70], particularly by reducing stomatal and CO_2 mesophyll conduction [71] and reducing chlorophyll content, which may affect light absorption [68,72]. In radish, about 80 percent of the decrease in salt growth can be attributed to a decrease in leaf expansion and consequently a decrease in light barrier. The remaining 20% effect of salt on growth was due to a decrease in stomach behavior [73]. Salt reduces the photosynthetic capacity of the plant, reduces leaf growth and inhibits photosynthesis, reducing its ability to grow [74]. The accumulation of salt in the root zone causes further osmotic pressure and disrupts cell ion homeostasis by interacting with both the barrier to the absorption of essential nutrients such as K +, Ca2 +, and NO3- and the accumulation of Na + and Cl- [75]. Special ion toxicity occurs in the tissues that transport the leaves at temporary levels due to the accumulation of sodium, chloride, and / or boron. The accumulation of harmful ions can inhibit photosynthesis and protein synthesis, degrade enzymes, and damage chloroplasts and other organisms [76]. These effects are especially important on older leaves, as they are the ones that last longer, so they accumulate more ions [63]. Plant deficiency and nutrient deficiencies may be due to the high concentration of Na + and Cl- soil solutions found in ion competition (i.e., Na + / Ca2 +, Na + / K +, Ca2 + / Mg + +, and Cl- / NO3- in plant tissues) [77]. When the level of Na + / Ca2 + in groundwater is high, symptoms of calcium deficiency are common. However, the low levels of calcium absorbed by tomato plants are associated with decreased respiration resulting from Na + competition [78]. Decreases in plant biomass, leaf area, and growth have been observed in various vegetable crops under salt stress [79,80]. The effects of salt stress on root formation / morphology are currently poorly understood (Maggio, 2011). However, root biomass is generally reported to be less susceptible to salinity than surface organisms [29]. Reduced salinity of biomass roots has been reported in broccoli and cauliflower [80] and root length density (RLD) in tomatoes [81]. Significant symptoms of salt damage appear gradually in plant growth. The first signs of salt stress are leaves, yellow leaves and growing growth. In the second stage the damage is seen as chlorosis of the green parts, burning of the leaf head, and necrosis of the leaves, and the oldest leaves are burning [82]. Lack of salt reduces marketable yields leading to reduced productivity and increases the non-market yield of fruits, roots, cereals and leaves that are not commercially viable. Irrigation with salt water has been shown to increase the likelihood of blight rot on tomatoes, fruit peppers, and brinjal, a nutritional deficiency associated with Ca2 + deficiency. However, more salt has a positive effect, which is the quality of the edible portion of vegetable vegetables. In general, salt stress, in addition to the obvious appearance (size, shape, and absence of defects), improves the quality of the edible portion of vegetable vegetables. Typically, too much salt increases the content of dried fruit, the content of soluble solids content (TSS) and the acidity of watermelon, tomatoes, sweet peppers and cucumbers. Salt stress increases carotenoid content and tomato antioxidant activity [83]. Overall, the nutritional quality (e.g., glucosinolate, polyphenol content, etc.) of edible broccoli flowers was improved under moderate saline pressure [84]. In Roman lettuce, the number of carotenoids increased in salt [85]. Salt pressure has increased polyphenol content and reduced nitrate particles as well as harmful oxalic spinach fixation [86]. The effect of salt on vegetable yields and quality was also affected during the application of salt pressure, which may be particularly important for improved irrigation (e.g., irrigation) and fertilizer management techniques. In two watermelons (Galia and Amarillo Oro), the yield of salt fruit did not decrease due to pressure from infection to harvest in the salt plant, and both increased fruit yield (TSS) and indicative of ripening in cultivation [87].

2.6 Management Practices

The key to vegetable production is to control the level of salt in the root zone equal to or below the plant ECt. To control salt levels, management should include the separation of saline soils and sodic soils, and fertilization and irrigation procedures should prevent soil salinity and reduce soil salt effects and / or increase salt irrigation in the growth and development of vegetable crops.

2.6.1 Soil reclamation

The problem of soil salinity and sodicity is difficult to solve; in order to do so, salt must be removed from the root zone (Reclamation). In addition to leaching, changes to increase soil permeability and lower variable sodium levels may be required for sodic soil reclamation. Sodic Reclamation is the process of replacing sodium in the soil with calcium ions by increasing the amount of gypsum in the soil ($CaSO_4$). The sodium ions are leached deep beyond the root zone with more water and eventually run out of the field via drainage. When gypsum is slowly mixed with water, calcium ions are released, which convert sodium ions into water that flows downward from the soil.

Table 8. Management of salinity

Management process	Application in Vegetables	Sources
Leaching of salt	The higher the salt of the irrigation water, the more leaching occurs in bell peppers.	[88]
Primer & elated herbs	As a companion plant, Salsola soda is utilised.	[89]
Mulching the Soil	Mulching with gravel and rice straw improves crop yields in Swiss chard.	[90]
Potassium	Potato - to increase the yield of tuber.	[91]
Calcium	Tomatoes and peppers help to prevent blossom end rot and improve fruit quality and yield.	[91]
Nitrogen	1 mM ammonium and 7 mM nitrate are used to reduce the impact of salt on fruit yield.	[93]
Phosphorus	The susceptibility to salinity was lowered by radish to a level of 3.5 dS m^{-1}.	[94]
Sulphur	Increased salinity stress-defense systems in brassica and legume crops.	[95]
Zinc	Under saline circumstances, pepper-Zn prevented excess Na uptake.	[96]
Biofertilizer	Phosphorine and Nitrobein in lettuce raises proline and glycine levels.	[97]
Manures	The negative effects of salt stress were mitigated by pepper-humic acid.	[98]
Non-nutritional additives are used	The activities of SOD and CAT are increased in spinach when it is exposed to salt.	[99]
CO_2 concentrations that are too high	Increased CO2 content in the atmosphere from tomatoes reduces the detrimental effects of salinity.	[100]
Relative Humidity	Melons-cultivars grow better in salt stress at 70% relative humidity than at 30% relative humidity.	[100]
Bacteriological inoculation	Artichoke-Bacillus subtilis inoculation reduced the negative effects of salt and enhanced productivity.	[102]
Priming of seeds	Melon seeds soaked in an 18 dS m1 NaCl solution reduce the harmful effects of saline irrigation.	[103]
Grafting with tolerant rootstocks	When melon and pumpkin rootstocks are combined, pumpkin rootstocks restrict 74 percent of available Na, whereas melon rootstocks exclude almost none.	[104]
Antioxidants that aren't enzymes are used.	It was discovered that adding 100 mM ascorbic acid to the nutrient solution alleviates the negative effects of salt in bean plants.	[105]
Plant growth regulators are used to control the growth of plants	Tomatoes with 0.5 mM salicylic acid enhance the accumulation of Na in plant tissues, which can then be used as osmolytes.	[106]
Solutes that are compatible	Brinjal- Exogenous glycinebetaine (GB) treatment results to improved growth and yield.	[107]
Nutrient application on the leaves	Brinjal-K2HPO4 resulted in a higher fruit output.	[108]

2.6.2 Fertilization

One of the wellsprings of soil salinization is crop fertilisation. Fertilizer properties, fertiliser application methods, irrigation water quality, and fertilisation scheduling, among other things, should be examined to reduce this unfavourable effect. Excessive nutrient applications should be avoided, and high-purity, chloride-free, low-saline fertilisers should be used instead. The nutritional requirements of irrigated vegetable crops must be met by nutrients in the soil, fertiliser, and irrigation water. Irrigation water with high nutrient levels (e.g., nitrate-N, calcium, magnesium, sulphur, and boron) may be sufficient to meet crop needs partially or completely [109]. The intensity of salt stress in the root zone, species, cultivar, nutrient source, and fertiliser administration method all influence plant response to fertilisers. However, fertiliser application in brackish soil can help to reduce salinity [110]. The usage of bio fertiliser can help to lessen the impact of salt on plants as well as the salinity of the soil. An organic fertiliser is a prepared product that contains one or more microorganisms that improve plant nutrient status (and thus growth and yield) by either replacing soil nutrients, making nutrients more available to plants, or increasing plant access to nutrients. Plant growth-promoting bacteria (PGPR), endo- and ectomycorrhizal fungi, and a variety of other beneficial microbes boost nutrient uptake, plant development, and salt tolerance. Seeds of many crop plants, such as tomato, black pepper, beans, and lettuce, can be vaccinated with PGPR to boost root and shoot growth, dry weight, fruit and seed yield, and salt stress tolerance in plants [111].

2.6.3 Irrigation

It is possible to reduce the effects of soil and water salinity by influencing irrigation method, management (irrigation determination and leaching fraction), and artificial drainage water-use efficiency (WUE) and nutrient-use efficiency, salt accumulation and distribution, and salt leaching by influencing irrigation method, management (irrigation determination and leaching fraction), and artificial drainage water-use efficiency (WUE) and nutrient-use efficiency, salt accumulation and distribution, and salt leaching. Irrigation methods such as surface drip irrigation (DI) and subsurface drip irrigation (SDI), furrow irrigation, and low energy precision application (LEPA) irrigation must be employed when foliar damage from salts in irrigation water is a concern. DI and SDI, when compared to other irrigation systems, allow for improved salinity management by boosting water and nutrient efficiency [112,113]. Furthermore, salt is largely leached from the soil inside the wet bulb, where root density is maximum, resulting in an adequate root-zone salinity (ECE ECT). Water travels in a more or less radial manner around the emitter in drip irrigation, and the ions eventually reflect this pattern. Water and ions move in a circular pattern with SDI irrigation, and salts accumulate near the soil surface, which can be a considerable obstacle to sown vegetable crops and/or transplanted plants in the early stages of development. Soil salinity affects almost all crops. This can result in subpar levels, resulting in lower plant population densities and, as a result, lower yields. Soil-soluble salts concentrate with the wetting front, upon its completion or convergence with another wetting front, when mulching or irrigation is used. The salts are concentrated in the intermediate regions between adjacent furrows when they are irrigated. To keep salt accumulation away from germinating seeds and plant roots, bed sizing and planting layouts are frequently utilised tactics. Salts are frequently transferred below the core region using sprinkler watering and an appropriate leaching proportion. When saltwater is utilised for irrigation, however, crops are at risk of additional loss due to salt dissipation in the leaves, as well as burn from spray contact with the foliage. The severity of harm is determined by the weather: the driest hot state occurs when evaporation concentrates salts on the leaf surface. As a result, when the temperature is the coldest, sprinkling irrigation with saline water should be done [114].

2.7 Maintenance Leaching

Maintenance leaching is required to enable long-term land use with irrigated vegetable crops. In addition to the amount required for general irrigation, the amount of water to be applied with irrigation should include a quantity that degrades the root zone. The leaching fraction refers to the extra water. Leaching is extremely necessary for long-term irrigation success [115].

2.8 Reclamation and Management of Sodic Soils

Gypsum: Soluble calcium salts (e.g., gypsum and calcium chloride), acids or acid-forming compounds (e.g., sulfuric acid, iron sulphate, sulphur, and pyrite), and low-solubility calcium salts (e.g., powdered limestone) are all examples. It is possible to lower soil ESP to less than 15 by using this method. However, gypsum ($CaSO4.2H_2O$) has altered the balance in favour of gypsum ($CaSO4.2H_2O$) as the amendment of choice to address sodicity-induced anomalies in soil physical characteristics due to reasons such as low cost, easy availability, convenience of application, and better efficacy compared to other chemicals. Gypsum boosts the availability of interchangeable Ca2+, allowing excess Na+ to be removed from the soil exchange complex. Gypsum has long been utilised on agricultural land as an ameliorant and a calcium and sulphur fertiliser source. Gypsum as a soil conditioner to prevent soil erosion and nitrogen depletion caused by run-off [116].

Gypsum-bed technology: To lower the risk of sodicity in locations with residual sodium carbonate water, gypsum is required. The gypsum can be integrated into the soil or poured into the irrigation channel (in a gunny bag) to be slowly dissolved by the descending tube well water. However, using specifically designed gypsum dissolving beds yields significantly superior outcomes [117]. The irrigation water is channelled through a brick-cement chamber containing a gypsum clod in the gypsum-bed method. The chamber's size is determined by the rate of residual sodium carbonate and the outflow of irrigation water tube wells. On one side, it's connected to the water fall box, and on the other, it's connected to the water channel. At a height of 10 cm from the chamber's floor, a mesh of iron bars coated with a wire net (2 mm x 2 mm) is put. Farmers can also transform their tube wells into gypsum rooms with the right improvements. Sodic water running from the bottom dissolves and refills the gypsum in the chamber [118]. Regardless of the application technique, the reason for determining the gypsum requirement remains the same. The application time, on the other hand, varies depending on the method used. When applying gypsum to soil, the full amount is applied as a single basal dose. Because water-applied gypsum is neutralised before it is applied, there is no build-up in the soil [117].

Organic materials have been proven to be beneficial in the form of heavy dressings of organic manures, regular inclusion of agricultural residues, rice hulls, sawdust, sugar mill waste, and so on. Maintaining and improving soil physical qualities, as well as countering the negative impacts of high fluctuating salt levels. If there is a risk of alkalinity in organic waters, organic matter should be applied whenever possible. However, organic modification alone, without the addition of gypsum, is ineffective in reducing the deleterious effects of alkali water. With the addition of gypsum to potato, tomato, eggplant, broccoli, cluster bean, cauliflower, cabbage, knol-khol, bottle gourd, ridge gourd, and bitter gourd, FYM boosted yields under water [60]. With the addition of gypsum and FYM, the negative effects of alkaline water resulted in a considerable rise in crop growth and yield parameters. They hypothesised that the high alkalinity with high pH disrupted the physicochemical environment of the rhizosphere, causing tuber emergence to be delayed. Because of the low levels of potato, the harmful effects of salt in the soil solution are also to blame. The emergence of germ tubers was further delayed by the creation of hard crusts on the soil surface due to precipitated carbonate and bicarbonate [119].

3. CONCLUSION

Producing vegetable crops necessitates a large amount of fertiliser and water, potentially raising soil salinity. Vegetable development, crop salt tolerance, soil ownership and water use efficiency, and impact on soil diversity should all be considered in fertilisation and irrigation management schemes. Biofertilizers have the ability to improve vegetable crop salt tolerance while also lowering soil salinity. With gypsum, FYM enhanced yields of potato, tomato, eggplant, broccoli, cluster bean, cauliflower, cabbage, knol-khol, bottle gourd, ridge gourd, and bitter gourd grown in alkali water. Vegetables, among crops, hold a special place in the human diet due to their nutritional content, which includes vitamins, carbs, proteins, and minerals. Nowadays, salinity is one of the most common abiotic stressors that inhibits plant growth and output. All elements of vegetable development, including growth, physical activity, and yield, are affected by salt. Where efforts have been made to improve salt tolerance in vegetables, strategies have been created to develop a salt-resistant species, usually using conventional breeding procedures to allow biotechnological technologies to be used. Planting salt can be used to cultivate the salt-affected land. Salt stress can be reduced by using tolerant species and tolerant root stock transplants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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