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Review

Soil Salinity: Effect on Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization

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Abstract: Salinity is a major problem affecting crop production all over the world: 20% of cultivated land in the world, and 33% of irrigated land, are salt-affected and degraded. This process can be accentuated by climate change, excessive use of groundwater (mainly if close to the sea), increasing use of low-quality water in irrigation, and massive introduction of irrigation associated with intensive farming. Excessive soil salinity reduces the productivity of many agricultural crops, including most vegetables, which are particularly sensitive throughout the ontogeny of the plant. The salinity threshold (EC_t) of the majority of vegetable crops is low (ranging from 1 to 2.5 dS m^{-1} in saturated soil extracts) and vegetable salt tolerance decreases when saline water is used for irrigation. The objective of this review is to discuss the effects of salinity on vegetable growth and how management practices (irrigation, drainage, and fertilization) can prevent soil and water salinization and mitigate the adverse effects of salinity.

Keywords: vegetable crops; salinity threshold; crop salt tolerance; ion imbalance; irrigation; drainage; fertilization

1. Introduction

Soil salinization is a major factor contributing to the loss of productivity of cultivated soils. Although difficult to estimate accurately, the area of salinized soils is increasing, and this phenomenon is especially intense in irrigated soils. It was estimated that about 20% (45 million ha) of irrigated land, producing one-third of the world's food, is salt-affected [1]. Soil salinity affects an estimated 1 million hectares in the European Union, mainly in the Mediterranean countries, and is a major cause of desertification. In Spain, 3% of the 3.5 million hectares of irrigated land is severely affected, markedly reducing its agricultural potential, while another 15% is under serious risk [2]. In the Mediterranean region, land degradation associated with soil alkalization may worsen at increasing rates in the coming decades, owing to the expected increase in irrigated areas and the increasing scarcity of good quality water [3]. The amount of world agricultural land destroyed by salt accumulation each year is estimated to be 10 million ha [4]. This rate can be accelerated by climate change, excessive use of groundwater (mainly if close to the sea), increasing use of low-quality water in irrigation, and massive introduction of irrigation associated with intensive farming and poor drainage. On the other hand, the tendency to increase the efficiency of irrigation water use, as is verified in many regions due to the scarcity of water, and the use of low quality water can lead to the accumulation of salts in the soil, since the leaching fraction is reduced and the salts contained in the irrigation water are not leached enough. It is estimated that, by 2050, 50% of the world's arable land will be affected by salinity [5]. Soil salinity reduces the productivity of many agricultural crops, including most vegetable crops, which present low tolerance to soil salinity. However, a substantial increase in production and consumption of vegetable crops that include edible portions of herbaceous species (roots, tubers, shoots, stems, leaves, fruits, and flowers) is a global priority. In fact, vegetables play an important role in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals, and dietary fiber. Some of the world's most widespread and debilitating nutritional disorders, such as micronutrient deficiencies, are related to low vegetable intake [6]. Generally, vegetables are crops with high productivity per unit of water applied and economic value compared with field crops. This may be a very important advantage for small farmers, because vegetables can grow in small areas, under intensive procedures. Vegetable crops generally require more water and more frequent irrigation than other agronomic crops. Vegetable crop production in arid and semi-arid regions with low rainfall and high temperatures require a larger input of fertilizers and irrigation. However, soil and water salinity increase are closely related to irrigation and fertilization practices. Therefore, the objective of this review is to analyze the effects of salinity on vegetable growth and how management practices (irrigation and fertilization) can prevent soil and water salinization and mitigate adverse effects of salinity.

2. Effects on Vegetable Growth and Nutrition

Salts affect plant growth due to increasing soil osmotic pressure and to interference with plant nutrition. A high salt concentration in soil solution reduces the ability of plants to acquire water, which is referred to as the osmotic or water-deficit effect of salinity. Damage occurs when the concentration is high enough to begin reducing crop growth. The osmotic effect of salinity induces metabolic changes in the plant identical to those caused by water stress-induced "wilting" [7] and shows few genotype differences [8]. Moreover, salt stress reduces plant growth due to specific-ion toxicities and nutritional imbalances [9] or a combination of these factors [10]. Indeed, salinity effects on plant growth reduction are a time-dependent process, and Munns et al. [11] proposed a two-phase model to depict the response of plant growth to salinity. The first phase is very rapid and growth reduction is ascribed to development of a water deficit. The second phase is due to the accumulation of salts in the shoot at toxic levels and is very slow. Despite the fact that this model has been demonstrated in broccoli [12], the relative importance of the two mechanisms on yield reduction is difficult to assess with confidence because they overlap.

Salinity affects photosynthesis by decreasing CO_2 availability as a result of diffusion limitations [13] and a reduction of the contents of photosynthetic pigments [14,15]. Salt accumulation in spinach inhibits photosynthesis [16], primarily by decreasing stomatal and mesophyll conductances to CO_2 [17] and reducing chlorophyll content, which can affect light absorbance [14,18]. In radish, about 80% of the growth reduction at high salinity could be attributed to reduction of leaf area expansion and hence to a reduction of light interception. The remaining 20% of the salinity effect on growth was most likely explained by a decrease in stomatal conductance [19]. Salinity lowers the total photosynthetic capacity of the plant through decreased leaf growth and inhibited photosynthesis, limiting its ability to grow [20].

Salt accumulation in the root zone causes the development of osmotic stress and disrupts cell ion homeostasis by inducing both the inhibition in uptake of essential elements such as K^+, Ca^{2+}, and NO_3^- and the accumulation of Na^+ and Cl^- [21]. Specific ion toxicities are due to the accumulation of sodium, chloride, and/or boron in the tissue of transpiring leaves to damaging levels. Accumulation of injurious ions may inhibit photosynthesis and protein synthesis, inactivate enzymes, and damage chloroplasts and other organelles [22]. These effects are more important in older leaves, as they have been transpiring the longest so they accumulate more ions [7]. Plant deficiencies of several nutrients and nutritional imbalances may be caused by the higher concentration of Na^+ and Cl^- in the soil solution derived from ion competition (i.e., Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+}, and Cl^-/NO_3^- in plant tissues) [23]. Calcium deficiency symptoms are common when the Na^+/Ca^{2+} ratio is high in soil water. However, lower calcium uptake by tomato plants has been linked with decreased transpiration rate rather than competition effects with Na^+ [24].

A decrease in plant biomass, leaf area, and growth has been observed in different vegetable crops under salt stress [25,26]. Salt stress effects on root architecture/morphology currently are poorly understood [27]. However, root biomass has been reported to be generally less affected by excess salinity than aboveground organs [10]. Salinity reduced root biomass has been reported in broccoli and cauliflower [26] and root length density (RLD) in tomato [28].

Visual symptoms of salt injury in plant growth appear progressively. The first signs of salt stress are wilting, yellowed leaves, and stunted growth. In a second phase the damage manifests as chlorosis of green parts, leaf tip burning, and necrosis of leaves, and the oldest leaves display scorching [29].

Salt stress decreases marketable yield due to decreased productivity and an increased unmarketable yield of fruits, roots, tubers, and leaves without commercial value. Irrigation with saline water has been shown to enhance the occurrence of blossom-end rot in tomato, pepper fruits, and eggplants, a nutritional disorder related to Ca^{2+} deficiency. However, salinity has some favorable effects on the quality of the edible part of the vegetable crops. In general, salt stress, with the exception of visual appearance (size, shape, and absence of defects), improves the quality of edible part of vegetable crops. In general, salinity increased fruit dry matter content, total soluble solids (TSS), and acid content of melon, tomato, sweet pepper, and cucumber. Salt stress increased carotenoid content and antioxidant activity of tomato [30]. Overall, the nutritional quality (e.g., glucosinolate, polyphenol content, etc.) of the edible florets of broccoli was improved under moderate saline stress [31]. In romaine lettuce, salinity increased carotenoid content [32]. Salt stress increased polyphenol content and decreased nitrate ion and oxalic acid concentration in spinach [33]. The effect of salinity on vegetable yield and quality was also affected by the timing of application of salt stress, which could be important for improved irrigation (e.g., deficit irrigation) and fertilization management strategies. In two melon cultivars (Galia and Amarillo Oro), the application of salt stress from fruiting to harvest did not reduce marketable fruit yield and increased fruit quality (TSS) and maturity index in both cultivars [34].

3. Alkalization

Salinity can affect plant growth indirectly by sodium's effect on the degradation of the soil's physical condition and by increasing the soil's pH. In normal soils with some organic matter content, exchangeable cations such as Ca^{2+} and Mg^{2+} link clay particles to humic acids of the organic matter, generating stable micro-aggregates which are the basis for soil structure, porosity, and internal drainage. In soils with high concentrations of sodium, calcium and magnesium adsorbed on the soil exchange complex will be replaced by sodium, which has low flocculating power (Table 1), causing dispersion of soil particles. The damage to soil structure is accompanied by an increase in the compactness of soils and a decrease in infiltrability, hydraulic conductivity, and the oxygen availability in the root zone. Another effect of a high concentration of sodium is increased pH (alkalization), which is produced by the presence of HCO_3^- and CO_3^{2-}. There is a linear relationship between the exchangeable sodium percentage (ESP) and the pH of the soil [35]. Excess sodium (Na^+) in the soil competes with Ca^{2+}, K^+, and other cations to reduce their availability to crops. Therefore, soils with high levels of exchangeable sodium (Na^+) may impact plant growth by dispersion of soil particles, nutrient deficiencies or imbalances, and specific toxicity to sodium sensitive plants.

Table 1. Influence of the cations on relative flocculating power.

Cation	Hydrated Radius (nm)	Relative Flocculating Power
Na^+	0.77	1.0
K^+	0.53	1.7
Mg^{2+}	1.08	27.0
Ca^{2+}	0.96	43.0

Source: Sumner and Naidu [36].

4. Vegetable Tolerance to Salinity

The salinity tolerance of any crop is defined as the ability to endure the effects of excess salt in the root zone. Salt tolerance is described by models that relate the decrease in relative production with the increase in soil salinity [37–39]. In the model of Maas and Hoffman [37], relative crop yield is not affected until a salinity threshold (EC_t) is exceeded, according to the following equation: $Y = 100 - (EC_e–ECt)\ S$. In this equation, Y is the relative crop yield, 100 is the maximum yield, EC_e is the salinity of soil saturation extract, EC_t (dS m^{-1}) is the threshold, the value of the electrical conductivity that is expected to cause the initial significant reduction in the maximum expected yield, and S is the slope that represents the percentage of yield expected to be reduced for each unit of added salinity above the EC_t. Salt crop tolerance is rated by salinity threshold (EC_t) and the percent of reduction of relative yield per unit increase in soil salinity above the threshold. The majority of vegetable crops have a salinity threshold that is $\leq$2.5 dS m^{-1} [28] (Table 2). Thus, the area of soils with restrictions for vegetable crop production is certainly greater than the area of salinized soils, since a saline soil is generally defined as showing an electrical conductivity (EC) value of the saturation extract (EC_e) in the root zone that exceeding 4 dS m^{-1} (approximately 40 mM NaCl) at 25 °C and having an exchangeable sodium level of 15% [1]. The Maas-Hoffman model only considers soil salinity and species; however, salt tolerance depends on many factors such as plant growth stage, climate, and salt type [29,40], soil properties [38], root-zone temperature [41], air concentration of CO_2 [42], and cultural practices (e.g., leaching fraction), etc. Therefore, the salt tolerances of different vegetable crops presented in Table 2 serve only as a guideline to assess relative tolerances among the crops. Concerning plant salt sensitivity relative to the growth stage, a general observation is that plants at earlier growth stages (seedling, establishment) are more sensitive to salt stress than plants at later stages. During germination and emergence, determination of tolerance is based on percent survival, while during the later developmental stages, tolerance is usually measured as relative growth reductions [8]. Salinity affected cauliflower growth mainly when imposed in the first growth phase [43]. The EC of irrigation water also affected salt tolerance [44] (Table 2). The lowest threshold level of irrigation water EC_w not restricting crop growth was 0.7 dS m^{-1}, lower than EC_e (1 dS m^{-1}) (Table 2). The majority of vegetable crops present low tolerance to saline water applied continuously (Table 2). The classes of salt tolerance are: sensitive, moderately sensitive, moderately tolerant, tolerant, and unsuitable for crops. The majority of vegetable crops are sensitive or moderately sensitive [38,45] (Table 2). Asparagus has been considered the most salt-tolerant vegetable crop.

Table 2. Salt tolerance of vegetable crops as determined by soil salinity (EC_e) and irrigation water salinity (EC_W).

Vegetable	Soil		Irrigation Water	Rating [2]
	Threshold [1] ($dS\cdot m^{-1}$) EC_e	Slope (% per $dS\cdot m^{-1}$)	Threshold [2] ($dS\cdot m^{-1}$) EC_W	
Asparagus	4.1	2.0	2.7	T
Bean	1.0	19.0	0.7	S
Broccoli	2.8	9.2	1.9	MS
Carrot	1.0	14.0	0.7	S
Cauliflower	-	-	1.9	MS
Celery	1.8	6.2	1.2	MS
Eggplant	1.1	6.9	0.7	MS
Lettuce	2.0	13.0	0.9	MS
Muskmelon	1.0	1.0	-	MS
Okra	1.2	-	-	S
Onion	1.2	16.0	0.8	S
Pea	1.5	14.6	-	MS
Pepper	1.5	14.0	1.0	MS
Potato	1.7	12.0	1.1	MS
Purslane	6.3	9.6	-	MT
Red beet	4.0	-	2.7	MT
Spinach	2.0	7.6	1.3	S
Strawberry	1.0	33.0	0.7	S
Tomato	2.5	9.9	1.7	MS

[1,2] Adapted from Maas and Hoffman [37], Maas and Grattan [46] and Grattan [44]—Data not available. EC_e—electrical conductivity (EC) of saturated paste extract of soil. EC_W—electrical conductivity (EC) of irrigation water.[2] S = sensitive, MS = moderately sensitive, MT = moderately tolerant, T = tolerant

5. Management Practices

The key to producing vegetable crops is to control salinity levels in the root zone to values equal to or smaller than the EC_t of a crop. In order to control salinity levels, management must include soil reclamation of the saline and sodic soils, and the practices of the fertilization and irrigation should aim to prevent soil salinization and to mitigate the effect of soil salinization and/or use of saline irrigation water in the growth and development of vegetable crops.

5.1. Soil Reclamation

Soil salinity and sodicity are problems too difficult to overcome, requiring salt removal from the root zone (reclamation). This is perhaps the most effective and long-lasting way to minimize or even eliminate detrimental effects of salinity [7]. However, in addition to being slow and expensive, the process requires large quantities of quality water and effective soil drainage. It is not always easy to obtain enough quality water, because the possible water sources next to the soils to be treated may already themselves be highly saline. If soil drainage is poor and the water table is shallow, an artificial drainage system must be installed. Consequently, it is not always possible or feasible to carry out a "true reclamation" technique. The reclamation of sodic soils may, in addition to leaching, require the application of amendments to increase soil permeability and reduce the exchangeable sodium levels. Sodic soils reclamation involves substituting sodium in the soil with calcium ions, through applying large quantities of gypsum ($CaSO_4$). The released sodium ions are then leached deep beyond the root zone using excess water and finally moved out of the field through drainage. Gypsum, when slowly mixed with water, releases calcium ions, which replace sodium ions from the soil into the downward moving water. Sulfuric acid and elemental sulfur (S^0) can also be used as alternatives to gypsum, because soil microbes convert sulfur into sulfuric acid ($S^0 + \frac{1}{2}O_2 + CO_2 + 2H_2O - H_2SO_4 + CH_2O$). The effect of S^0 amendment could be slower, because sulfur oxidation depends on soil temperature, humidity, and aeration, etc. Sulfuric acid and elemental sulfur addition also contribute to soil pH reduction, due to an increase of the H_3O^+ in soil solution.

5.2. Fertilization

Crop fertilization is one of the sources of salinization of soils. To reduce this negative impact, the fertilizer characteristics, the method of fertilizer application, irrigation water quality, and fertilization scheduling, etc., must be considered. Excessive nutrient applications must be avoided, and high-purity, chloride-free, low-saline fertilizers should be selected. In irrigated vegetable crops the crop nutritional requirements must by supplied by the soil, fertilization, and the nutrient content in the irrigation water. Irrigation waters could contain high nutrient levels (e.g., nitrate-N, calcium, magnesium, sulfur, and boron) sufficient to partially or completely satisfy crop needs [44,47]. Many agricultural regions in the world have high amounts of N in the groundwater due to NO_3 leaching from fertilizers [47]. Ca^{2+}, Mg^{2+}, and $SO_4{}^{2+}$ concentrations in irrigation water may easily exceed apparent uptake concentrations [48].

The application of fertilizers through irrigation water (fertigation) can reduce soil salinization and mitigate salt stress effects because it improves the efficiency of fertilizer use, increases nutrient availability and timing of application, and the concentration of fertilizers are easily controlled. Fertigation allows frequent applications of very low fertilizer rates which adjusts nutrient supply to plant requirements. Nutrient supply rate must take into account the rates of nutrient uptake and of evapotranspiration and irrigation water quality. The solutions applied in fertigation should generate low additions of EC_w and should not exceed the EC_t (electrical conductivity threshold) tolerated by the crops, which varies with the irrigation water and with the fertilizer used [49,50]. The application of fertilizers in irrigation waters with EC_w values of >0.7 d*S* m^{-1} (Table 2) must be made carefully. Nitric acid and sulfuric acid fertigation represent rapid ways to reduce or minimize salinity and sodicity in arid regions. Nitric acid applied with fertigation reduces soil pH and increases Ca^{2+} dissolution in clay soils, thereby minimizing salinity injury due to Ca^{2+}/Na^+ competition. It may also reduce chloride salinity in the root zone, because the nitrate can counterbalance the excess of chloride [51]. In arid regions, soils are commonly alkaline, with high concentrations of free calcium carbonate ($CaCO_3$). In this case, sulfuric acid can be applied by fertigation, with a consequent release and leaching of the Na^+ existing in the soil profile [52]. Iron must be supplied in chelated form (Fe-DTPA Fe-EDDHA) to increase it availability to plants.

The salt tolerance of the crops could be improved by the addition of different nutrients [53]. Plant response to fertilizers depends on severity of salt stress in the root zone [46] the species, cultivar, nutrient source, and fertilizer application method. However, the application of fertilizers to saline soils also may exacerbate soil salinization [46]. The strategy used in the addition of inorganic fertilizers is mainly based in competition between ions (one ion limits the uptake of another ion).

The addition of $NO_3{}^-$, Ca^{2+}, K, P, salicylic acid, and silicon (Si) to the saline medium or in foliar application has improved salt tolerance of numerous vegetable crops such as tomato, pepper, eggplant, melon, bean, strawberry, etc. (Table 2). Increasing the nitrate content in a nutrient solution would decrease chloride uptake and its accumulation [54]. However, several studies have shown that under salt stress conditions the effects of salinity can be alleviated by application of nitrate and ammonium compared to growth on only nitrate or ammonium [55]. The ratio of $NO_3{}^-/NH_4{}^+$ most appropriate to improve salt tolerance depends on the crop [56,57]. In tomato, the deleterious effect of salinity on biomass production can be minimized by the use of nutrient solutions containing higher $NH_4{}^+$ concentrations [56]. Although deemed a “non-essential” mineral nutrient, Si has been shown to be effective in mitigating salinity effects on several vegetable crops (Table 3). Si decreased the root-to-shoot translocations of Na^+, Cl^-, and boron in tomato plants grown on a sodic-B toxic soil [58]. The majority of these results were obtained under controlled conditions. Therefore, it is necessary to study the effect of these substances in salt tolerance of vegetable crops in field conditions.

Humic substances can ameliorate the deleterious effects of salt stress by increasing root growth, altering mineral uptake, and decreasing membrane damage, thus inducing salt tolerance [59]. The addition of humic acids to the saline medium improved salt tolerance of different crops (Table 3). Applications of humic acids enhanced K^+/Na^+ and Ca^{2+}/Na^+ ratios in pepper [60].

The use of biofertilizers can also mitigate salinity effects on vegetables and reduce soil salinization. A biofertilizer could be defined as a formulated product containing one or more microorganisms that enhance the nutrient status (and the growth and yield) of the plants by either replacing soil nutrients, by making nutrients more available to plants, and/or by increasing plant access to nutrients. Plant growth promoting rhizobacteria (PGPRs), endo- and ectomycorrhizal fungi, and many other useful microscopic organisms led to improved nutrient uptake, plant growth, and plant tolerance to salt stress. The inoculation of seeds of various crop plants, such as tomato, pepper, bean, and lettuce, with PGPRs can result in increased root and shoot growth, dry weight, fruit, and seed yield and enhanced tolerance of plants to salt stress [61]. PGPR and Si synergistically enhanced salinity tolerance of the mung bean [62]. The use of arbuscular mycorrhiza (AM) has been shown to be able to alleviate salt stress in tomato, onion, and lettuce [63–65]. Biofertilizers can reduce soil salinization by reducing application of fertilizers, improving soil fertility by fixing atmospheric N_2, both in association with plant roots and independent of roots, solubilizing insoluble soil phosphates, and producing plant growth substances in the soil.

Table 3. Nutrients that improved salt tolerance in different vegetable crops.

Nutrients	**Crop**	**References**
Humic acid	Bean	Aydin et al. [66]
P		Bargaz et al. [67]
KH_2PO_4	Eggplant	Elwan [68]
KNO_3	Melon	Kaya et al. [69]
Humic acid	Okra	Paksoy et al. [70]
Humic acid	Pepper	Bacilio et al. [60]
Silicon		Manivannan et al. [71]
Salicylic acid	Strawberry	Karlidag et al. [72]
Calcium		Kaya et al. [73]
Salicylic acid	Tomato	Stevens et al. [74], Mimouni et al. [75],
KNO_3		Satti and Lopez [76]
Silicon		Romero-Aranda et al. [77], Al-Aghabary et al. [78]
P and K	Spinach	Kaya et al. [79]
Salicylic acid	Cucumber	Yildirim et al. [80]
Silicon		Zhu et al. [81]
Silicon	Zucchini squash	Savvas et al. [82]

5.3. Irrigation

Irrigation method, management (irrigation scheduling and leaching fraction), and artificial drainage can prevent and mitigate the effects of soil and water salinity by influencing water-use efficiency (WUE) and nutrient-use efficiency, salt accumulation and distribution, and salt leaching. Where foliar damage by salts in irrigation water is a concern, irrigation methods such as surface drip irrigation (DI) and subsurface drip irrigation (SDI), furrow irrigation, and low energy precision application (LEPA) irrigation must be used. DI and SDI, compared with other irrigation methods, allow for better salinity management by increasing water-use efficiency and nutrient-use efficiency [49,83,84]. Additionally, soil inside the wet bulb, where root density is the highest, is mostly salt leached, which creates a suitable root-zone salinity ($EC_e < EC_t$). Under drip irrigation, water moves in a more or less radial pattern around the emitter and the ions eventually mirror this pattern [45]. In the wet bulb, the ions tend to accumulate in the interface between the dry soil and wetting front due to the difference in osmotic potential [85], mainly next to the soil surface [45].

An appropriate irrigation scheduling with DI and SDI methods can also reduce the effects of salinity by continuously maintaining moist soil around plant roots and providing steady leaching of salt to the edge of the wetted zone. SDI, in comparison with DI, increased water use-efficiency in tomato [49,86] and reduced sodium and chloride accumulations in tomato plant tissues on a silty clay soil in Tunisia [87]. Under SDI irrigation, water and ions flow in spherical manner and the salts accumulate near the soil surface, which may constitute a significant constraint for vegetable crops sown and/or transplanted, because most crops at an early juvenile development stage are more susceptible to soil salinity. This can reduce plant population density to suboptimal levels and consequently impact the yield. With furrow irrigation, soluble salts in the soil move with the wetting front, concentrating at its termination or at the convergence with another wetting front. When adjacent furrows are irrigated, salts concentrate in the middle spaces between furrows. Manipulating bed shape and planting arrangements are strategies often used to ensure that the zones of salt accumulation stay away from germination seeds and plant roots. Sprinkler irrigation and an appropriate leaching fraction generally move salts below the root zone. However, when saline water is used with irrigation, the crops are potentially subject to additional damage caused by salt uptake into the leaves, and burn from spray contact with the leaves. The degree of injury depends on weather conditions: it is most severe during hot dry conditions, because evaporation concentrates the salts at the leaf surface. Therefore, sprinkler irrigation with saline water must be done when temperatures are coolest.

When irrigation water is scarce, as due to the occurrence of a drought, the irrigation schedule may include deficit irrigation strategies. Deficit irrigation (DI) is an optimization strategy in which the application of water is smaller than the full crop evapotranspiration requirements. Water restriction is applied, outside of drought-sensitive growth stages of a crop, during which yield loss due to water stress may be compensated by the value of saved water. Deficit irrigation may increase WUE and vegetable quality, but imposes some degree of yield reduction and increases the risk of soil salinization due to reducing leaching. Partial root-zone drying (PRD), a modified form of deficit irrigation, in which the two halves of the root are alternately irrigated, increased WUE and did not affect yield in tomato [88] and in potato [89].

5.4. Maintenance Leaching

To ensure long-term land use with irrigated vegetable crops, it is necessary to do a maintenance leaching. The volume of water applied with irrigation must include a water amount that drains down the root zone, which is in addition to the amount required for normal irrigation. This additional water is defined as the leaching fraction (LF) [90]. Leaching is absolutely necessary to achieve long-term successful irrigation [90,91]. A LF of 15 to 20% is commonly recommended [21]. The required frequency of leaching varies with the degree of salinization and evaporative demand [92] and salt sensitivity of the crops [84]. In arid regions, LF must be included in each irrigation event [52]. The frequency of leaching when drip irrigation is used could be two or three times a week or daily for moderately sensitive and sensitive salt crops, respectively [84].

6. Conclusions

Soil salinity is becoming a major constraint to vegetable crop production. Vegetable crop production requires a high input of fertilizers and water, each possibly increasing soil salinity. Fertilization and irrigation management strategies must consider the effects of salinity on vegetable growth, crop salt tolerance, soil proprieties, and effects on water use efficiency and soil salinity. Drip irrigation and subsurface drip irrigation, compared with other irrigation systems, increase water use efficiency and create a suitable root-zone salinity ($EC_e < EC_t$). Fertigation increases nutrient use efficiency and allows fertilizer application without provoking excessive increases in soil salinity. Salt tolerance of vegetable crops can be enhanced by applying some nutrients (e.g., silicon, humic acid, etc.). Biofertilizers also have the potential to increase salt tolerance of vegetable crops and reduce soil salinization.

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References

1. Shrivastava, P.; Kumar, R. Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi J. Biol. Sci.* **2015**, *22*, 123–131. [CrossRef] [PubMed]
2. Stolte, J.; Tesfai, M.; Øygarden, L.; Kværnø, S.; Keizer, J.; Verheijen, F.; Panagos, P.; Ballabio, C.; Hessel, R. *Soil threats in Europe: Status, Methods, Drivers and Effects on Ecosystem Services. A Review Report, Deliverable 2.1 of the RECARE Project*; Office for Official Publications of the European Community: Luxembourg, 2015; Vol. EUR 27607, pp. 69–78.
3. Bowyer, C.; Withana, S.; Fenn, I.; Bassi, S.; Lewis, M.; Cooper, T.; Benito, P.; Mudgal, S. *Land Degradation and Desertification Policy Department Economic and Scientific Policy IP/A/ENVI/ST/2008-23*; European Parliament: Brussels, Belgium, 2009.
4. Pimentel, D.; Berger, B.; Filiberto, D.; Newton, M.; Wolfe, B; Karabinakis, E.; Clark, S.; Poon, E.; Abbett, E.; Nandaopal, S. Water Resources: Agricultural and Environmental Issues. *BioScience* **2004**, *54*, 909–918. [CrossRef]
5. Bartels, D.; Sunkar, R. Drought and salt tolerance in plants. *Crit. Rev. Plant Sci.* **2005**, *24*, 23–58. [CrossRef]
6. Increasing Fruit and Vegetable Consumption Becomes a Global Priority. Available online: http://www.erails.netconsulted (accessed on 2 February 2017).
7. Munns, R.; Husain, S.; Rivelli, A.R.; Richard, A.J.; Condon, A.G.; Megan, P.L.; Evans, S.L.; Schachtman, D.P.; Hare, R.A. Avenues for increasing salt tolerance of crops, and the role of physiologically based selection traits. *Plant Soil* **2002**, *247*, 93–105. [CrossRef]
8. Läuchli, A.; Grattan, S.R. Plant growth and development under salinity stress. In *Advances in Molecular Breeding toward Drought and Salt Tolerant Crops*; Springer: Dordrecht, The Netherlands, 2007; pp. 1–32.
9. Läuchli, A.; Epstein, E. Plant responses to saline and sodic conditions. In *Agricultural Salinity Assessment and Management*; Tanji, K.K., Ed.; American Society of Civil Engineers: Reston, VA, USA, 1990; Volume 71, pp. 113–137.
10. Munns, R.; Tester, M. Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.* **2008**, *59*, 651–681. [CrossRef] [PubMed]
11. Munns, R.; Schachtman, D.P.; Condon, A.G. The significance of a two-phase growth response to salinity in wheat and barley. *Funct. Plant Biol.* **1995**, *22*, 561–569. [CrossRef]
12. López-Berenguer, C.; García-Viguera, C.; Carvajal, M. Are root hydraulic conductivity responses to salinity controlled by aquaporins in broccoli plants? *Plant Soil* **2006**, *279*, 13–23. [CrossRef]
13. Flexas, J.; Diaz-Espejo, A.; Galmés, J.; Kaldenhoff, R.; Medrano, H; Ribas-Carbo, M. Rapid variations of mesophyll conductance in response to changes in CO_2 concentration around leaves. *Plant Cell Environ.* **2007**, *30*, 1284–1298. [CrossRef] [PubMed]
14. Delfine, S; Alvino, A.; Villani, M.C.; Loreto, F. Restrictions to carbon dioxide conductance and photosynthesis in spinach leaves recovering from salt stress. *Plant Physiol.* **1999**, *119*, 1101–1106. [CrossRef] [PubMed]
15. Ashraf, M.; Harris, P.J.C. Photosynthesis under stressful environments: An overview. *Photosynthetica* **2013**, *51*, 163–190. [CrossRef]
16. Di Martino, C.; Delfine, S.; Alvino, A.; Loret, F. Photorespiration rate in spinach leaves under moderate NaCl stress. *Photosynthetica* **1999**, *36*, 233–242. [CrossRef]
17. Delfine, S.; Alvino, A.; Zacchini, M.; Loreto., F. Consequences of salt stress on conductance to CO_2 diffusion, Rubisco characteristics and anatomy of spinach leaves. *Funct. Plant Biol.* **1998**, *25*, 395–402. [CrossRef]
18. Alvino, A.; D'Andria, R.; Delfine, S.; Lavini, A.; Zanetti, P. Effect of water and salinity stress on radiation absorption and efficiency in sunflower. *Ital. J. Agron.* **2000**, *4*, 53–60.

19. Marcelis, L.F.M.; Van Hooijdonk, J. Effect of salinity on growth, water use and nutrient use in radish (*Raphanus sativus* L.). *Plant Soil* **1999**, *215*, 57–64. [CrossRef]
20. Yeo, A.R. Salinity. In *Plant Solute Transport*; Yeo, A.R., Flowers, T.J., Eds.; Blackwell: Oxford, UK, 2007; pp. 340–365.
21. Paranychianakis, N.V.; Chartzoulakis, K.S. Irrigation of Mediterranean crops with saline water: From physiology to management practices. *Agric. Ecosyst. Environ.* **2005**, *106*, 171–187. [CrossRef]
22. Taiz, L.; Zeiger, E. *Plant Physiology*, 3rd ed.; Publisher Sinauer: Sunderland, UK, 2002; p. 690.
23. Grattan, S.R.; Grieve, C.M. Mineral element acquisition and growth response of plants grown in saline environments. *Agric. Ecosyst. Environ.* **1992**, *38*, 275–300. [CrossRef]
24. Adams, P.; Ho, L.C. Effects of constant and fluctuating salinity on the yield, quality and calcium status of tomatoes. *J. Hortic. Sci.* **1989**, *64*, 725–732. [CrossRef]
25. Zribi, L.; Gharbi, F.; Rezgui, F.; Rejeb, S.; Nahdi, H.; Rejeb, M.N. Application of chlorophyll fluorescence for the diagnosis of salt stress in tomato "*Solanum lycopersicum* (variety Rio Grande)". *Sci. Hortic.* **2009**, *120*, 367–372. [CrossRef]
26. Giuffrida, F.; Scuderi, D.; Giurato, R.; Leonardi, C. Physiological response of broccoli and cauliflower as affected by NaCl salinity. *Acta Hortic.* **2013**, *1005*, 435–441. [CrossRef]
27. Maggio, A.; De Pascale, S.; Fagnano, M.; Barbieri, G. Saline agriculture in Mediterranean environments. *Ital. J. Agron.* **2011**, *6*, 7. [CrossRef]
28. Snapp, S.S.; Shennan, C.; Bruggen, A.V. Effects of salinity on severity of infection by *Phytophthora parasitica* Dast., ion concentrations and growth of tomato, *Lycopersicon esculentum* Mill. *New Phytol.* **1991**, *119*, 275–284. [CrossRef]
29. Shannon, M.C.; Grieve, C.M. Tolerance of vegetable crops to salinity. *Sci. Hortic.* **1998**, *78*, 5–38. [CrossRef]
30. De Pascale, S.; Maggio, A.; Orsini, F.; Stanghellini, C.; Heuvelink, E. Growth response and radiation use efficiency in tomato exposed to short-term and long-term salinized soils. *Sci. Hortic.* **2105**, *189*, 139–149. [CrossRef]
31. López-Berenguer, C.; Martínez-Ballesta, M.D.C.; Moreno, D.A.; Carvajal, M.; García-Viguera, C. Growing hardier crops for better health: Salinity tolerance and the nutritional value of broccoli. *J. Agric. Food Chem.* **2009**, *57*, 572–578. [CrossRef] [PubMed]
32. Kim, H.J.; Fonseca, J.M.; Choi, J.; Kubota, C.; Kwon, D.Y. Salt in irrigation water affects the nutritional and visual properties of romaine lettuce (*Lactuca sativa* L.). *J. Agric. Food Chem.* **2008**, *56*, 3772–3776. [CrossRef] [PubMed]
33. Shimomachi, T.; Kawahara, Y.; Kobashigawa, C.; Omoda, E.; Hamabe, K.; Tamaya, K. Effect of residual salinity on spinach growth and nutrient contents in polder soil. *Acta Hortic.* **2008**, *797*, 419–424. [CrossRef]
34. Botía, P.; Navarro, J.M.; Cerdá, A.; Martínez, V. Yield and fruit quality of two melon cultivars irrigated with saline water at different stages of development. *Eur. J. Agron.* **2005**, *23*, 243–253. [CrossRef]
35. Khajanchi, L.; Meena, R.L. Diagnosis of soil and water for salinity'. In *Conjunctive Use of Canal and Groundwater*; Intech Graphics: Karnal, India, 2008; pp. 57–66.
36. Sumner, M.E.; Naidu, R. *Sodic Soils Distribution, Properties, Management, and Environmental Consequences*; Oxford University Press: New York, NY, USA, 1998.
37. Maas, E.V.; Hoffman, G.J. Crop salt tolerance—Current assessment. *ASCE J. Irrig. Drain. Div.* **1977**, *103*, 115–134.
38. Maas, E.V. Crop salt tolerance. In *Agricultural salinity assessment and management; ASCE Manuals and Reports on Engineering Practice*; Tanji, K.K., Ed.; American Society of Civil Engineers: Reston, VA, USA, 1990.
39. Genuchten, M.T.; Hoffman., G.J. Analysis of crop salt tolerance data. In *Soil Salinity under Irrigation, Processes and Management, Ecological Studies*; Shainberg, I., Shalhevet., J., Eds.; Springer: New York, NY, USA, 1984; Volume 3, pp. 258–271.
40. Ayers, R.S.; Westcot, D.W. Water quality for agriculture. In *FAO Irrigation and Drainage Paper 29 (Rev. 1)*; Food and Agricultural Organization: Rome, Italy, 1985.
41. Dalton, F.N.; Maggio, A.; Piccinni, G. Effect of root temperature on plant response functions for tomato: Comparison of static and dynamic salinity stress indices. *Plant Soil* **1997**, *192*, 307–319. [CrossRef]
42. Maggio, A.; Dalton, F.N.; Piccinni, G. The effects of elevated carbon dioxide on static and dynamic indices for tomato salt tolerance. *Eur. J. Agron.* **2002**, *16*, 197–206. [CrossRef]

43. Giuffrida, F.; Carla, C.; Angelo, M.; Cherubino, L. Effects of salt stress imposed during two growth phases on cauliflower production and quality. *J. Sci. Food Agric.* **2016**, *97*, 1552–1560. [CrossRef] [PubMed]
44. Grattan, S. *Irrigation Water Salinity and Crop Production*; UCANR Publications, University of California: Oakland, CA, USA, 2002; p. 9.
45. Hanson, B.; Grattan, A.; Fulton, A. *Agricultural Salinity and Drainage; Davis, California Irrigation Program WMS (Water Management Series) 3375*; University of California: Oakland, CA, USA, 2006; pp. 1–159.
46. Maas, E.V.; Grattan, S.R. Crop yields as affected by salinity. *Agronomy* **1999**, *38*, 55–110.
47. Machado, R.M.A.; Bryla, D.R.; Verissimo, M.L.; Sena, A.M.; Oliveira, M.R.G. Nitrogen requirements for growth and early fruit development of drip-irrigated processing tomato (*Lycopersicon esculentum* Mill.) in Portugal. *J. Food Agric. Environ.* **2008**, *6*, 215–218.
48. Sonneveld, C.; Voogt, W. *Plant Nutrition of Greenhouse Crops*; Springer: New York, NY, USA, 2009; p. 423.
49. Machado, R.M.A. Estudos Sobre a Influência da Rega-Gota-a-Gota Subsuperficial na Dinamica de Enraizamento, no Rendimento Físico e na Qualidade da Matéria-Prima do Tomate de Indústria. Ph.D. Thesis, Universidade de Évora, Évora, Portugal, 2002.
50. Machado, R.M.; Bryla, D.R.; Vargas, O. Effects of salinity induced by ammonium sulfate fertilizer on root and shoot growth of highbush blueberry. *Acta Hortic.* **2014**, *1017*, 407–414. [CrossRef]
51. Xu, G.; Magen, H.; Tarchitzky, J.; Kafkafi, U. Advances in chloride nutrition of plants. *Adv. Agron.* **1999**, *68*, 97–150.
52. Silvertooth, J.C. Fertigation in Arid Regions and Saline Soils Fertigation. In Selected Papers of the IPI-NATESC-CAU-CAAS, Proceedings of the International Symposium on Fertigation, Beijing, China, 20–24 September 2005; pp. 20–24.
53. Shahbaz, M.; Ashraf, M.; Al-Qurainy, F.; Harris, P.J.C. Salt tolerance in selected vegetable crops. *Crit. Rev. Plant Sci.* **2012**, *31*, 303–320. [CrossRef]
54. Martinez, V.; Cerda, A. Influence of N source on rate of Cl, N, Na and K uptake by cucumber seedling grown in saline condition. *J. Plant Nutr.* **1989**, *12*, 971–983. [CrossRef]
55. Ghanem, M.E.; Martínez-Andújar, C.; Albacete, A.; Pospíšilová, H.; Dodd, I.C.; Pérez-Alfocea, F.; Lutts, S. Nitrogen form alters hormonal balance in salt-treated tomato (*Solanum lycopersicum* L.). *J. Plant Growth Regul.* **2011**, *30*, 144–157. [CrossRef]
56. Flores, P.; Carvajal, M.; Cerda, A.; Martinez, V. Salinity and ammonium/nitrate interactions on tomato plant development, nutrition, and metabolites. *J. Plant Nutr.* **2001**, *24*, 1561–1573. [CrossRef]
57. Sandoval-Villa, M.; Wood, C.W.; Guertal, E.A. Effects of nitrogen form, nighttime nutrient solution strength, and cultivar on greenhouse tomato production. *J. Plant. Nutr.* **1999**, *22*, 1931–1945. [CrossRef]
58. Gunes, A.; Inal, A.; Bagci, E.G.; Coban, S.; Sahin, O. Silicon increases boron tolerance and reduces oxidative damage of wheat grown in soil with excess boron. *Biol. Plant.* **2007**, *51*, 571–574. [CrossRef]
59. Ouni, Y.; Ghnaya, T.; Montemurro, F.; Abdelly, C.; Lakhdar, A. The role of humic substances in mitigating the harmful effects of soil salinity and improve plant productivity. *Int. J. Agron. Plant Prod.* **2014**, *8*, 353–374.
60. Bacilio, M.; Moreno, M.; Bashan, Y. Mitigation of negative effects of progressive soil salinity gradients by application of humic acids and inoculation with Pseudomonas stutzeri in a salt-tolerant and a salt-susceptible pepper. *Appl. Soil Ecol.* **2016**, *107*, 394–404. [CrossRef]
61. Egamberdieva, D.; Lugtenberg, B. Use of plant growth-promoting rhizobacteria to alleviate salinity stress in plants. In *Use of Microbes for the Alleviation of Soil Stresses*; Miransari, M., Ed.; Springer: New York, NY, USA, 2014; Volume 1, pp. 73–96.
62. Mahmood, S.; Daur, I.; Al-Solaimani, S.G.; Ahmad, S.; Madkour, M.H.; Yasir, M.; Ali, Z. Plant Growth Promoting Rhizobacteria and Silicon Synergistically Enhance Salinity Tolerance of Mung Bean. *Front Plant Sci.* **2016**, *7*, 876. [CrossRef] [PubMed]
63. Latef, A.A.H.A.; Chaoxing, H. Effect of arbuscular mycorrhizal fungi on growth, mineral nutrition, antioxidant enzymes activity and fruit yield of tomato grown under salinity stress. *Sci. Hortic.* **2011**, *127*, 228–233. [CrossRef]
64. Cantrell, I.C.; Linderman, R.G. Preinoculation of lettuce and onion with VA mycorrhizal fungi reduces deleterious effects of soil salinity. *Plant Soil* **2001**, *233*, 269–281. [CrossRef]
65. Aroca, R.; Ruiz-Lozano, J.M.; Zamarreño, Á.M.; Paz, J.A.; García-Mina, J.M.; Pozo, M.J.; López-Ráez, J.A. Arbuscular mycorrhizal symbiosis influences strigolactone production under salinity and alleviates salt stress in lettuce plants. *J. Plant Physiol.* **2013**, *170*, 47–55. [CrossRef] [PubMed]

66. Aydin, A.; Canan, K.; Metin, T. Humic acid application alleviate salinity stress of bean (*Phaseolus vulgaris* L.) plants decreasing membrane leakage. *Afr. J. Agric. Res.* **2012**, *7*, 1073–1086. [CrossRef]
67. Bargaz, A.; Nassar, R.M.A.; Rady, M.M.; Gaballah, M.S.; Thompson, S.M.; Brestic, M.; Abdelhamid, M.T. Improved Salinity Tolerance by Phosphorus Fertilizer in Two *Phaseolus vulgaris* Recombinant Inbred Lines Contrasting in Their P-Efficiency. *J. Agron. Crop Sci.* **2016**, *202*, 497–507. [CrossRef]
68. Elwan, M.W. Ameliorative effects of di-potassium hydrogen orthophosphate on salt-stressed eggplant. *J. Plant Nutr.* **2010**, *33*, 1593–1604. [CrossRef]
69. Kaya, C.; Tuna, A.L.; Ashraf, M.; Altunlu, H. Improved salt tolerance of melon (*Cucumis melo* L.) by the addition of proline and potassium nitrate. *Environ. Exp. Bot.* **2007**, *60*, 397–403. [CrossRef]
70. Paksoy, M.; Türkmen, Ö.; Dursun, A. Effects of potassium and humic acid on emergence, growth and nutrient contents of okra (*Abelmoschus esculentus* L.) seedling under saline soil conditions. *Afr. J. Biotechnol.* **2010**, *9*, 5343–5346.
71. Manivannan, A.; Soundararajan, P.; Muneer, S.; Ko, C.H.; Jeong, B.R. Silicon Mitigates Salinity Stress by Regulating the Physiology, Antioxidant Enzyme Activities, and Protein Expression in Capsicum annuum 'Bugwang'. *BioMed Res. Int.* **2016**, *2016*, 3076357. [CrossRef] [PubMed]
72. Karlidag, H.; Yildirim, E.; Turan, M. Salicylic acid ameliorates the adverse effect of salt stress on strawberry. *Sci. Agric.* **2009**, *66*, 180–187. [CrossRef]
73. Kaya, C.; Ak, B.E.; Higgs, D. Response of salt-stressed strawberry plants to supplementary calcium nitrate and/or potassium nitrate. *J. Plant Nutr.* **2003**, *26*, 543–560. [CrossRef]
74. Stevens, J.; Senaratna, T.; Sivasithamparam, K. Salicylic acid induces salinity tolerance in tomato (*Lycopersicon esculentum* cv. Roma): Associated changes in gas exchange, water relations and membrane stabilisation. *Plant Growth Regul.* **2006**, *49*, 77–83.
75. Mimouni, H.; Wasti, S.; Manaa, A.; Gharbi, E.; Chalh, A.; Vandoorne, B.; Ahmed, H.B. Does Salicylic Acid (SA) Improve Tolerance to Salt Stress in Plants? A Study of SA Effects on Tomato Plant Growth, Water Dynamics, Photosynthesis, and Biochemical Parameters. *Omics* **2016**, *20*, 180–190. [CrossRef] [PubMed]
76. Satti, S.M.E.; Lopez, M. Effect of increasing potassium levels for alleviating sodium chloride stress on the growth and yield of tomato. *Commun. Soil Sci. Plant Anal.* **1994**, *25*, 2807–2823. [CrossRef]
77. Romero-Aranda, M.R.; Jurado, O.; Cuartero, J. Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. *J. Plant Physiol.* **2006**, *163*, 847–855. [CrossRef] [PubMed]
78. Al-Aghabary, K.; Zhu, Z.; Shi, Q.H. Influence of silicon supply on chlorophyll content, chlorophyll fluorescence, and antioxidative enzyme activities in tomato plants under salt stress. *J. Plant Nutr.* **2004**, *27*, 2101–2115. [CrossRef]
79. Kaya, C.; Higgs, D.; Kirnak, H. The effects of high salinity (NaCl) and supplementary phosphorus and potassium on physiology and nutrition development of spinach. *Bulg. J. Plant Physiol.* **2001**, *27*, 47–59.
80. Yildirim, E.; Turan, M.; Guvenc, I. Effect of foliar salicylic acid applications on growth, chlorophyll, and mineral content of cucumber grown under salt stress. *J. Plant Nutr.* **2008**, *31*, 593–612. [CrossRef]
81. Zhu, Z.; Wei, G.; Li, J.; Qian, Q.; Yu, J. Silicon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt-stressed cucumber (*Cucumis sativus* L.). *Plant Sci.* **2004**, *167*, 527–533. [CrossRef]
82. Savvas, D.; Giotis, D.; Chatzieustratiou, E.; Bakea, M.; Patakioutas, G. Silicon supply in soilless cultivations of zucchini alleviates stress induced by salinity and powdery mildew infections. *Environ. Exp. Bot.* **2009**, *65*, 11–17. [CrossRef]
83. Malash, N.M.; Flowers, T.J.; Ragab, R. Effect of irrigation methods, management and salinity of irrigation water on tomato yield, soil moisture and salinity distribution. *Irrig. Sci.* **2008**, *26*, 313–323. [CrossRef]
84. Hanson, B.; May, D. *Drip Irrigation Salinity Management for Row Crops; Publication 8447*; University of California: Oakland, CA, USA, 2011; pp. 1–13.
85. Pizarro, F. *Riegos Localizados de Alta Frequência*; Goteo, Microaspersion, Exudacion, Ediciones Mundi-Prensa: Madrid, España, 1996; p. 513.
86. Lamm, F.R. Cotton, tomato, corn and onion production with subsurface drip irrigation: A review. *Trans. ASABE* **2016**, *59*, 263–278.
87. Kahlaoui, B.; Hachicha, M.; Rejeb, S.; Rejeb, M.N.; Hanchi, B.; Misle, E. Effects of saline water on tomato under subsurface drip irrigation: Nutritional and foliar aspects. *J. Soil Sci. Plant Nutr.* **2011**, *11*, 69–86. [CrossRef]

88. Kirda, C.; Cetin, M.; Dasgan, Y.; Topcu, S.; Kaman, H.; Ekici, B.; Derici, M.R.; Ozguven, A.I. Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation. *Agric Water Manag.* **2004**, *69*, 191–201. [CrossRef]
89. Liu, F.; Shahnazari, A.; Andersen, M.N.; Jacobsen, S.E.; Jensen, C.R. Effects of deficit irrigation (DI) and partial root drying (PRD) on gas exchange, biomass partitioning, and water use efficiency in potato. *Sci. Hortic.* **2006**, *109*, 113–117. [CrossRef]
90. Letey, J.; Hoffman, G.J.; Hopmans, J.W.; Grattan, S.R.; Suarez, D.; Corwin, D.L.; Oster, J.D.; Wu, L.; Amrhein, C. Evaluation of soil salinity leaching requirement guidelines. *Agric. Water Manag.* **2011**, *98*, 502–506. [CrossRef]
91. Hoffman, G.J.; Rhoades, J.D.; Letey, J.; Sheng., F. Salinity management. In *Management of Farm Irrigation Systems (ASAE Monograph)*; Hoffman, G.J., Howell, T.A., Solomon, K.H., Eds.; American Society of Agricultural and Biological Engineers: St. Joseph, MI, USA, 1990; pp. 667–671.
92. Levy, Y.; Syvertsen, J.P. Irrigation water quality and salinity effects in citrus trees. *Hortic. Ver.* **2004**, *30*, 37–82.