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The Relations between Salinity and Mineral Nutrients on Some Vegetable Crops

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Abstract

Salinity is one of the major environmental factors that leads to a deterioration of agricultural land and reduction in crop productivity. On the other hand to increase the productivity of crop there is need to add mineral nutrient to soil to increase its fertility. While adding mineral nutrients salinity of the soil should be known to determine the nutrient that should be added prior to the vegetable that will be sown. The relationship of salinity and each mineral nutrient that we are going to use should be clearly known to determine the level of tolerance. Unless the interaction of the mineral nutrient and salinity is known application of different nutrient fertilizers wastage and may affect the growth and development of horticultural crops like vegetables. The yield we expect will not be achieved. In this review I have tried to assess the relationship of mineral nutrients and salinity in horticultural/vegetable crops.

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Salinity, macronutrients, micronutrients, relationships.

Introduction

Most horticultural crops are glycophytes (Greenway and Munns, 1980) and have evolved under conditions of low soil salinity. Salinity is one of the major environmental factors that leads to a deterioration of agricultural land and reduction in crop productivity worldwide (Munns, 2002; Viswanathan *et al.*, 2005). Salt stress is one of the major abiotic stress factors that affect almost every aspect of physiology and biochemistry of a plant, resulting in a reduction in its yield (Foolad, 2004). Thus it is a serious threat to agricultural productivity especially in arid and semi-arid regions (Parvaiz *et al.*, 2008).Salt stress causes hyperosmotic stress and ion disequilibrium, thereby disabling the vital cellular functions of a plant. Reduced availability of water, increased respiration rate, altered mineral distribution, membrane instability, failure in the maintenance of turgor pressure are some of the events that prevails during this stress episode. Plants try to withstand these stresses either by tolerating it or by adopting a dormant stage (Cuartero *et al.*, 2006). Salt tolerance effectors and regulatory components gain importance at this juncture.

Crops have developed mechanisms for absorbing, transporting and utilizing mineral nutrients from non saline substrates may not operate as efficiently or as effectively under saline as non-saline conditions. Na^+ and Cl^- concentrations often exceed those of most macronutrients by one or two orders of magnitude, and by even more in the case of micronutrients. Therefore, high concentrations of Na^+ and Cl^- in the soil solution may depress nutrient-ion activities and produce extreme ratios of Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+} and Cl^-/NO_3^-. As a result, the plant becomes susceptible to osmotic and specific-ion injury as well as to nutritional disorders that may result in reduced yield or quality (Grattan and Grieve, 1999).

Imbalances in nutrient can result in salt-stressed plants in various ways. Imbalances may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant or may be caused by physiological inactivation of a given nutrient resulting in an increase in the plant's internal requirement for that essential element (Grattan and Grieve, 1994). It is reasonable to believe that two or more of these processes may be occurring at the same time, but whether they ultimately affect crop yield or quality depends upon the salinity level, composition of salts, the crop species, the nutrient in question and a number of environmental factors.

The availability and uptake of nutrients by plants in saline environments are affected by many factors in the soil-plant environment. The solid phase of the soil and the concentration and composition of solutes in the soil solution controls the activity of the nutrient ion. Soil solution pH will influence the speciation and thus availability of certain nutrients. The concentration and ratios of accompanying elements can influence the uptake and transport of a particular nutrient and indirectly may affect the uptake and translocation of others. These interactions are complicated further by numerous environmental factors such as aeration, temperature, and stresses both biotic and abiotic. Crops vary not only in the rate at which they absorb an available nutrient element, but also in the manner by which they distribute the element spatially within the plant. Certain ions in the salinizing media such as sodium can have a profound effect on calcium mobility and distribution within certain plant organs (Grattan and Grieve, 1999).

The interactive nature affecting nutrient availability, uptake and distribution are topics that are highly complex in the absence of salinity or other stresses (Marschner, 1995). The presence of salinity adds a new level of complexity to the mineral nutrition of crops. Salinity not only affects yield potential of a plant but almost every aspect of physiology and biochemistry of a plant (Parvaiz *et al.,* 2008). According Babu *et al.,* (2012) chemical analysis of leaf and mature fruits showed a significant elevation in the levels of sodium ion concentration while K^+ and K^+/Na^+ decreased with application of higher concentrations of NaCl. The rates of increase in Na^+ content were higher in leaves than in fruits. The distribution of Na^+ varies among the organs of the plant. Potassium content was found to be decreasing with increase in salt stress. These outcomes suggest that there was a competition between Na^+ and K^+ regarding their uptake (Babu *et al.,* 2012).

Salinity and mineral-nutrient interaction studies are conducted in the laboratory, greenhouse, and in the field and correspondingly have a wide range of horticultural or physiological hypotheses that are to be tested. Many of the salinity-fertility trials conducted in the field attempted to address whether or not fertilization would increase crop salt tolerance. Several scientists have reviewed the literature on salinity-fertility studies in the field and concluded that a bulk of the results were contradictory (Adams and Doerge, 1987; Feigin, 1985). Many of the studies that were reviewed described experiments conducted in a variety of conditions but in most cases the soils or substrate were deficient in N, P and/or K^+. The reviewers found that plant growth was increased by nutrient application regardless of whether the plants were salt-stressed or not. This beneficial response does not, however, imply that fertilization increases salt-tolerance.

Interaction Effect of Salinity and Macronutrients

Most salinity and N interaction studies in the field were conducted on soils deficient in N. Therefore, additions of N improved growth and/or yield when the degree of salinity was not severe. An increase in crop yield under saline soils where N was applied above a level considered optimal under non-saline conditions (i.e. N-fertilization did not increase crop salt-tolerance). Many laboratory and greenhouse studies have shown that salinity can reduce N accumulation in plants (Pessarakli and Tucker, 1988; Feigin *et al.*, 1991). This is because of an increase in Cl^- uptake and accumulation is often accompanied by a decrease in shoot NO_3^-concentration. Such effect have been seen in eggplant (Savvas and Lenz, 1996).

The form in which N is supplied to salt-stressed plants can influence salinity N relations as well as affect salinity's relation with other nutrients (Lewis *et al.,* 1989). $NH4^+$ fed melon (Feigin, 1990) more sensitive to salinity than NO_3^- fed plants when grown in solution cultures. Martinez and Cerda (1989) noted that when $NO_3^+$was the only N-source, accumulation of K^+ in the plant was increased under saline conditions. When the media contained both NO_3 and NH_4^+, K^+ was reduced.

The salinity-N relations of horticultural crops are complex. Most of the studies indicated the N uptake or accumulation in the shoot may be reduced under saline conditions, although there are studies that found the opposite or no effect (Feigin, 1985). Nevertheless in those studies where NaCl-treated plants contained less N than non-stressed plants, there is no strong evidence to support the fact that this effect is growth-limiting (Munns and Termaat, 1986).

The interaction between salinity and phosphorus is highly dependent upon the plant species (or cultivar), plant developmental age, the composition and level of salinity and the concentration of P in the substrate. According to Champagnol (1979) P, added to saline soils, increased crop growth and yield in 34 of the 37 crops studied. Similar to the effect of added N, added P did not necessarily increase crop salt tolerance. After analysing studies including horticultural crops such as carrot, maize, sugar beet, *Beta vulgaris* L. and tomato, he concluded that added P increased, had no effect on, or decreased salt tolerance as salinity increased from low, to moderate, to high levels, respectively. In most cases, salinity decreases the concentration of P in plant tissue (Sharpley *et al.*, 1992), but the results of some studies indicate salinity either increased or had no effect on P uptake. Plant-growing conditions, plant type and even cultivar play a large role in P accumulation (Grattan and Grieve, 1994).

Under saline-sodic or sodic conditions, high levels of external Na not only interfere with K^+ acquisition by the roots, but also may disrupt the integrity of root membranes and alter their selectivity. The selectivity of the root system for K^+ over Na^+ must be sufficient to meet the levels of K^+ required for metabolic processes, for the regulation of ion transport, and for osmotic adjustment (Grattan and Grieve, 1999). A wide variety of horticultural crops have shown that K^+ concentration in plant tissue, expressed on a dry mass basis, declines as the Na^+-salinity or as the Na^+/Ca^{2+} in the root media is increased (Alfocea *et al.*, 1996). Sodium-induced K^+ deficiency has been implicated in growth and yield reductions of various crops, including tomato (Song and Fujiyama, 1996), spinach (Chow *et al.*, 1990). At the same time that K^+ uptake is impaired by salinity, higher K^+ levels in tissue are required for shoot growth. Potassium concentrations in salt-stressed plants depend on whether the source of nitrogen fertilization is $NH4^+$ or $NO3^-$. K^+ uptake by cucumber seedlings salinised with NaCl was inhibited by the combination of both NH_4^+ and NO_3^+ but stimulated by NO_3^+ alone. While this response may be primarily associated with the well-documented competition between K^+ and NH_4^+, Martinez and Cerda (1989) point out that the lower K^+ influx from substrates containing NH_4^+ may be due to changes in membrane potential and pH differentials.

As the salt concentration in the root zone of plant increases, plant requirement for Ca^{2+} also increases (Bernstein, 1975). At the same time, the uptake of Ca^{2+} from the substrate may be depressed because of ion interactions, precipitation, and increases in ionic strength. These factors reduce the activity of Ca2. In solution thereby decreasing Ca^{2+} availability to the plant (Cramer *et al.*, 1986; Suarez and Grieve, 1988). Severity of the calcium disorder depends on the kinds of ions that contribute to salinity and environmental conditions. Increased incidence and severity of calcium deficiency of artichoke buds were directly related to increased levels of salinity (supplied by NaCl and CaCl2). The number of marketable artichokes was reduced 20% when irrigation water salinity exceeded 2 dS/m, and up to 50% at 10 dS/m (Francois, 1995). Graifenberg *et al.*, (1995) observed no visible damage to artichoke buds in response to NaCl-salinity. He also reported only small reductions in calcium allocation to bud tissue as salt stress increased. In a field experiment conducted in Israel, the frequency of internal tip burn of Chinese cabbage increased with increasing salinity supplied by irrigation waters containing NaCl and CaCl2 3:1 molar ratio (Mizrahi and Pasternak, 1985).

Growth and yield reductions of Na-salinized tomato are generally ameliorated by increases in substrate calcium (Al-Harbi, 1995). Song and Fujiyama (1996) attributed this result to the suppression of sodium transport to the shoot rather than to the antagonism between Ca^{2+} and Na^+ at the root surface. The incidence of internal fruit rot of pepper and eggplant grown in salinized hydroponic cultures also increased in concert with increases in external Na^+/Ca^{2+} ratio (Savvas and Lenz, 1996). For both species, reduced calcium translocation to the fruit resulted in calcium deficiency which was confirmed by tissue ion analysis.

Interaction Effect of Salinity with Micronutrients

The relationship between salinity and trace element nutrition is complex and salinity may increase, decrease, or have no effect on the micronutrient concentration in plant shoots. Most studies on horticultural crops, regardless of whether they were conducted in soils or in solution cultures, indicate that salinity reduces Mn concentration in shoot tissue. Examples include bean (Doering *et al.,* 1984), squash, (Maas *et al.,* 1972) and tomato (Alam *et al.,* 1989).Salinity was also found to increase Mn concentration in sugar beet shoots (Khattak and Jarrell, 1989) but these investigators found that salt(NaCl+ CaCl2) additions increased Mn in the saturated soil extract, indicating that salt additions increased plant-available Mn. Zinc applications have been found to improve growth in salt-stressed plants (El-Sherif *et al.,* 1990) but benefits have been greater in sodic conditions than either saline or saline-sodic environments (Mehrotra *et al.,* 1986). Reports on the influence of salinity on the iron (Fe) concentration in plants are as inconsistent as those that concern Zn and Mn concentration. Salinity increased the Fe concentration in the shoots of pea (Dahiya and Singh, 1976), tomato, squash (Maas *et al.,* 1972).

Relationship of salinity and mineral nutrients of some vegetable crops

Tomato

Improvement for salinity tolerance would be of significant value for a moderately sensitive crop like tomato when it is grown on lands with salinity problems. Extensive research is being carried out to produce tomato plants with improved salt tolerance. Under saline condition as soon as new cell starts its elongation process, the excess of Na^+, Cl^- and other ions modifies the metabolic activities of cell wall, which causes deposition of several materials on cell wall and limits the cell wall elasticity (Yasar *et al.,* 2006). Cell walls become rigid and turgor pressure efficiency in cell enlargement is decreased with application of elevated salt treatment. The other anticipated cause of reduction in leaf area and dry matter content could be the reduced development and differentiation of tissues, shrinkage of the cell contents, unbalanced nutrition, damage of membrane and disturbed avoidance mechanism (Akram *et al.,* 2007).

According to Papadopoulos and Rendig (1983) tomato plants were grown with Typic Xerofluvents soil in a greenhouse irrigated with recycled nutrient solutions having increasing levels of N and salinity. Positive response of plants to increasing levels of N was obtained at the lowest initial salinity level of 1 dS/m. At the higher initial salinity levels of 5 and 9 dS/m, increasing N was ineffective in counteracting adverse effects on growth and yield caused by the presence of enhanced salt concentrations of the nutrient solution. Total N uptake was linearly correlated with the total water uptake and was severely suppressed by impaired growth associated with the two higher initial salinity levels, irrespective of N levels. The effect of salinity on leaf N concentrations changed over time. Leaf Cl and P concentrations indicated a possible suppressing effect of Cl on P uptake into plant tops. Awad *et al.,* (1990) found that when NaCl increased in the substrate from 10 to 50 to 100 mM, the P concentrations in the youngest mature tomato leaf necessary to obtain 50% yield increased from 58 to 77 to 97 mmol/kg dry weight, respectively.

Pot experiment done on tomato to investigate the effects of supplementary calcium sulphate on plants grown at high NaCl concentration showed that the plants grown under salt stress produced low dry matter, fruit weight, and relative water content than those grown in standard nutrient solution. Supplemental calcium sulphate added to nutrient solution containing salt significantly improved growth and physiological variables affected by salt stress (e.g. plant growth, fruit yield, and membrane permeability) and also increased leaf K^+, Ca^{2+}, and N in tomato plants. The effects of supplemental $CaSO_4$ in maintaining membrane permeability, increasing concentrations of Ca^{2+}, N, and K^+ and reducing concentration of Na^+ (because of cation competition in root zone) in leaves could offer an economical and simple solution to tomato crop production problems caused by high salinity (Tuna *et al.,* 2007). Another experiment done to test as Ca^{2+} absorption may vary in different tomato cultivar showed that shoot and root dry weight, and root length were depressed as salinity increased in plants lacking additional Ca^{2+} (Caines and Shennan, 1999).

Pepper

Salinity and low soil nutrient availability are important growth limiting factors for most plants. Research conducted to determine the effect of different level of nitrogen at different salinity condition on pepper indicates that over-fertilization during early plant development may contribute to salinity and decreased pod yield. While salt-stressed pepper performs well when adequately fertilized (Villa-Castorena *et al.,* 2003), N should be applied in amounts that increase with plant need over the growing season. Sodium (Na) concentration in plant tissues increased in pepper leaves and roots in the NaCl treatment. Concentrations of potassium (K) and Phosphorus (P) in leaves were lowered in salt treatment and almost fully restored by supplementary KH_2PO_4. These show that supplementary

KH_2PO_4 can partly mitigate the adverse effects of high salinity on both fruit yield and whole plant biomass in pepper and plants (Kaya, 2003).

Salinity reduced significantly the leaf K, Ca, and Mg uptake but not to levels that could cause nutrient deficiencies. These indicate that pepper is susceptible to high salinity, predominantly due to reduced stomatal conductance. However, after long-term exposure to salinity the growth may be suppressed due also to inhibition of photosynthesis at chloroplast level. The adverse effects of high NaCl-salinity are hardly mitigated when only a part of the root system is salinized, which indicates that the response is governed by root exposure to high NaCl concentrations and not by inefficiency of the roots to take up water (Lycoskoufis *et al.,* 2005). Günes (1996) also stated that as increasing salinity levels increased stomatal resistance and sodium (Na), chloride (Cl), proline contents of the plants. Potassium (K), total-nitrogen (N), and chlorophyll content of the plants were decreased under high salinity conditions.

Lettuce

Lettuce has been considered as a moderately salt sensitive crop, with a threshold electrical conductivity (EC) of 1.3 dS m-1, and a negative slope of 13.0 for each unit of added salinity above this threshold value (Ayers *et al.,* 1951). Nevertheless, the root growing media may affect the response of plants to salinity. Pasternak *et al.,* (1986) reported that yield and quality of soil grown lettuce was not affected by sprinkling with water at 4.4 dS m^{-1}.Andriolo *et al.,* (2005) reported that Lettuce growth was affected by low concentrations of the nutrient solution, probably due to low availability of mineral nutrients. Nevertheless, drymass accumulation was not reduced at concentrations of the nutrient solution higher than 2.8 dS m-1. This implies uptake of carbon by leaves and mineral nutrients by roots were not affected. Effects of salinity on plant growth and yield have been attributed to simultaneous reduction in leaf area and root growth, affecting photosynthesis and water and mineral uptake (Grieve, 1999).

Sodium chloride salinity has been shown to result in the increase Na+ and Cl- in tissues basal to the apical meristem in lettuce with a resultant decrease in Ca2+, K+, and PO_4^{2+} (Lazof and Lauchli, 1991). Such disruptions in ion compositions were hypothesized to affect nutrition of the apical meristem which might signal growth reduction in expanding leaves. Other studies indicate that while exogenously applied Ca2+ improved the nutritional levels of Ca2+ under salt stress and reduced Na accumulation, growth was not improved (Cramer and Spurr, 1986b). Using two lettuce cultivars that differed in salt tolerance, higher root Cl levels were found to be beneficial in maintenance of root water content (Cramer and Spurr, 1986a).

Carrot

Carrot is considered to be a salt sensitive vegetable (Bernstein and Ayers, 1953) Research on the effect of salt on carrot response to salinity stress is scarce. For example, shoot and root fresh and dry weights of carrot have been reported to be reduced markedly under saline conditions (Inal *et al.,* 2009). In storage roots, Na+, K+, Ca2+, and Cl− concentrations were considerably lower than those in the shoots under saline conditions (Inal *et al.,* 2009). As in most glycophytes shoot and root Na+ and Cl− concentrations increase significantly while those of K+ and Ca2+ decrease in the carrot plant under saline conditions. Salinity of the root growing medium reduces Br, S, and Si and increases Mg, Cu, Fe, Al, Cs, and Ni concentrations in carrot (Inal *et al.*, 2009).

The availability and uptake of nutrients by plants in saline environments are affected by many factors in the soil-plant environment. Imbalances in nutrient can result in salt-stressed plants in various ways. Imbalances may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant or may be caused by physiological inactivation of a given nutrient resulting in an increase in the plant's internal requirement for that essential element. Salinity and mineral-nutrient interaction studies are conducted in the laboratory, greenhouse, and in the field and correspondingly have a wide range of horticultural or physiological hypotheses that are to be tested. Many of the salinity-fertility trials conducted in the field attempted to address whether or not fertilization would increase crop salt tolerance.

Salinity and macronutrient relationship was conducted and there is a contradicting results. The salinity-N relations of horticultural crops are complex. For example some studies suggest that accumulation of NaCl in the shoot of plants may reduce the uptake of N but other say no effect. In most cases, salinity decreases the concentration of P in plant tissue. Plant-growing conditions, plant type and even cultivar play a large role in P accumulation. Higher K^+ levels in tissue are required for shoot growth but in saline condition it prefers ions while application of nitrogen. Different micronutrient also have different response to salinity depending on plant type. In general nutrient and salinity interaction have either positive or negative depending on crops preference and tolerance level. So for proper application of nutrient salinity tolerance level of horticultural crops should be studied for proper growth and high yield.

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