ALLEVIATION OF SALINITY- INDUCED STRESS IN CASH CROPS BY MULTI-K (POTASSIUM NITRATE), FIVE CASES TYPIFYING THE UNDERLYING PATTERN.

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Abstract

The use of enhanced potassic plant nutrition is an efficient method of preventing sodium-induced stress in many crops. In addition, the use of enhanced nitrate fertilization is a potent tool in precluding chloride-induced stress in many crops.
The application of Multi-K (potassium nitrate) is shown here as a very efficient method of combating the aforementioned stresses and enhancing crops performances under saline conditions. This concept is validated shown here for five moderately salinity-sensitive crops representing the three main sectors of agriculture: A) sweet corn for annual field crops, B) citrus for perennials, and C) tomato, lettuce and Chinese cabbage for greenhouse-grown vegetables. By adding Multi-K to their nutrition program, these crops were better able to cope with salinity conditions despite higher EC levels resulting from this treatment.

The incorporation of Multi-K at 2, 8 or 14 mM in the nutrition scheme of salinized sweet corn significantly increased dry matter production and ear yield.

Salinity treatments (6.6 – 18 mM of Cl^-) markedly increased Cl and Na contents of grapefruit leaves, thereby reducing the total yield of the trees and their canopy volumes, but had a minor effect on K content of the leaves. By maintaining a constant concentration of 2 mM Multi-K in the irrigation water, the adverse effects of salinity treatments on the trees were avoided. The resulting yields increased from 3 to 38%.

Salination (50 mM NaCl) of the nutrient solution of greenhouse tomatoes markedly decreased K content of the leaves, fruit-set rate, number of flowers, dry weights of the plants, fruit sizes and stem heights. Adding Multi-K at 2, 4 or 8 mM to the salinized nutrient solution reversed these effects, despite marked increase in EC. Moreover, several vegetative parameters were improved over the non-salinized controls.

Three levels of Multi-K (1, 5 and 10 mM) were tested on salinized (52 mM of Cl^-) hydroponically grown lettuce and Chinese cabbage. The highest yields of fresh weight of both crops were obtained from the 5 mM Multi-K treatment, under both saline and non-saline conditions. Salination increased the concentration of Na and Cl in plant tissue and reduced the levels of N and K; the opposite occurred in plants fed by the medium and high levels of Multi-K.

All the aforementioned results clearly demonstrate that plants can successfully cope with stresses imposed by 30-50 mM Na and Cl, by continuous application of Multi-K at 2–8 mM. A general model can explain all phenomena involved.

1. Introduction

The common dogma is that all deleterious effects of salinity are caused by two primary mechanisms. A) Non-specific, osmotic-related dehydration. B) Impact of accumulation of specific toxic ions (e.g. chloride, sodium, magnesium, sulfate and boron,) on plant cells and their adverse effects on crucial physiological processes.

An extensive list of studies (e.g. Bar *et al.*, Feigin, Kafkafi *et al*. 1971 & 1982) show that appropriate nitrate nutrition of assorted crops can prevent deleterious effects of soil-solution chloride. Other papers (e.g. Hepaksoy *et al.* and Taban *et al.*) have shown that K alleviates Na deleterious effects under sodic conditions. K also has an extremely important and unique role in the activation of numerous enzyme systems (Evans *et al.*).

It is the purpose of this paper to confirm that sodium and chloride ions are the key players in this system and that combating their uptake and reducing their involvement in plant physiology is more important than reducing high electrical conductivity (EC) of the soil solution. Furthermore, all experiments described clearly demonstrate that despite increasing the EC of irrigation water, a proper nutritional regime can reverse the negative effects of salinity and restore crops performances found at much lower salinity levels.

All experiments were done with crops deemed to possess (Maas) moderate sensitivities to salinity. All crops were irrigated with intentionally salinized water, and the performances were compared to a parallel treatment in which Multi-K (potassium nitrate) was added to water.

Multi-K is a binary, high quality specialty fertilizer. It is composed of 100% macronutrients: 13% nitrogen, all in nitrate (NO_3^-) form, and 46% K_2O. It is virtually free of sodium, chloride, perchlorate and other detrimental elements or harmful residues. It is readily and fully water-soluble, making it an ideal fertilizer for top-dressing, fertigation and foliar feeding.

This paper is a compilation of several representative studies (Imas *et al.*, Bar *et al*., Levy *et al*. Satti *et al.*, and Feigin *et al.*), featuring substantial data establishing the concept that constant application of minimal rates of potassium nitrate considerably aids in alleviating salinity problems. These results fit perfectly into the framework produced by Nitsos *et al.* (superiority of K for the activation of starch synthetase); Benzioni *et al*. (the specific role of K as a vehicle for transportation of nitrate and malate into and within the plant), and Ben-Asher *et al*. (validity of these models for saline environment).

2. Materials and methods

2.1. Sweet corn experiment

Sweet corn cv. Jubilee seedlings were grown in an aero-hydroponic system in Israel. A standard fertigation solution was salinized by 5 rates of a 4/1 (M/M) mixture of NaCl and $CaCl_2$, and augmented with 2, 8 or 14 mM of Multi-K. Plant performances were checked upon completion of development at 52 days after planting.

2.2. Citrus experiment

The experiment was performed in 1999 in an orchard, located in the Besor area, of Israel, with its arid climate and sandy soil. Marsh seedless nucellar grapefruit trees, 3 years old grafted on a variety of rootstocks were trickle-irrigated with intentionally salinized (NaCl & $CaCl_2$ at a w/w ratio of 2/1, respectively) water with salinity gradients of five increments, with or without Multi-K. Irrigation water parameters (including salination agents and fertilizers) were: chloride 234 – 636 mg L^{-1}, Na 6.8 – 15.3 mM, EC of the standard treatment 1.91 – 3.15 dS m^{-1}, and of the Multi-K enriched treatments 2.23 – 3.40 dS m^{-1}. Multi-K was applied to the trees at a constant concentration of 200 ppm with every irrigation cycle.

2.3. Greenhouse tomatoes experiment

Tomato plants of several cultivars were grown in a greenhouse in the Sultanate of Oman on an inert medium and fed by half-strength Hoagland solution. The EC of this control treatment was 1.2 dS m^{-1}. In the salinized treatment, 50 mM NaCl was added, thus increasing its EC to 5.5 dS m^{-1}. In other treatments, Multi-K at 2, or 4 mM was added to the salinized nutrient solution. Consequently, the EC values of these solutions increased considerably. Several vegetative- and yield parameters were recorded.

2.4.Chinese cabbage and lettuce experiment

Chinese cabbage (Pekinensis group, cv. *Kazumi*) and lettuce (cv. *Salinas*) were grown aero-hydroponically in a greenhouse in Israel. A standard nutrition solution was used as a control (1.8 dS m^{-1}) or salinized by NaCl and $CaCl_2$ at 34 and 9 mM, respectively (6 dS m^{-1}). Both of these solutions were augmented with 1, 5 or 10 mM of Multi-K. Plant performances were checked at 51 – 63 days after transplanting.

3. Results

3.1 Sweet corn experiment.

Total dry matter and ear yield shared a common salt-sensitivity pattern of linear decrease as the EC was elevated beyond the threshold value. Increasing Multi-K concentration from 2 to 14 mM increased dry matter production and ear yield, see figure 1.

3.2. Citrus experiment.

Salinity treatments markedly increased chloride and sodium contents of the leaves, reduced total yield of the trees and their canopy volumes, but had a minor effect on K contents of the leaves. Multi-K treatments, however, considerably counteracted these phenomena and increased yields between 3 and 38% for the various rootstocks (selected results are shown in figures 2-4).

3.3 Greenhouse- tomato experiment

As shown in figures 5 & 6 salination of the nutrient solution markedly decreased dry weight of the plant, fruit size, plant height, K content of the leaves, fruit-set rate and total number of flowers on the main stem of the plant. The addition of Multi-K to the salinized nutrient solution reversed the adverse effects caused by the NaCl, despite the marked increase in EC, involved in this measure. Several parameters were improved over the control as a direct result of the treatment with Multi-K, i.e., fruit size and plant height (figure 5) K content of the leaves and fruit-set rate (figure 6).

3.4. Chinese cabbage experiment

Salination of the nutrition solution resulted in the development of severe toxicity symptoms. Also, as shown in figure 7 yield dropped by 15% in the salination treatment. Adding 1 mM of Multi-K has further reduced the yield, but increasing Multi-K concentration to 5 mM significantly restored the yield to 109% and 127% of the non-saline, and the salinated treatments, respectively.

3.5. Lettuce experiment

Diameters of head of greenhouse- grown lettuce plants were markedly reduced in response to salination of the nutrition solution (data not shown). Consequently, as shown in figure 8 the yield of the plants was severely and significantly affected (-30%) by the salination. Adding 1 or 5 mM of Multi-K has significantly restored yield to 113% or 127% of the salinized treatment, respectively. Leaf analysis of the plants revealed a clear pattern of increase in K and N (Kjeldhal) and decrease in Na and Cl contents as a direct response of the Multi-K treatments (table 1).

4. Discussion

The results cited in this paper clearly show the benefits stemming from applying nitrate and potassium in the form of Multi-K (potassium nitrate) as an anti-salinity agent. The sweet corn experiment shows that the slope representing the damage caused by salinity was not altered by the treatments, but the threshold for salinity damage was considerably increased as Multi-K was employed at increasing rates (figure 1). Sweet corn plants were highly productive even at EC= 5 dS m^{-1} , a figure treble than the value stated by Maas for non-saline conditions. This finding may stem from the fact that K is the preferred monovalent cation in the photosynthetic system in maize, as found by Nitsos *et al*. Similar results were reported also for peanuts, which are another annual field crop, moderately sensitive to salinity (Silberbush *et al.*; Ben-Asher *et al.*).

The citrus experiment clearly shows that the constant application of Multi-K at a low rate of 200 ppm (2mM) in the irrigation water considerably alleviates salinity-induced vegetative stresses, thus markedly increasing commercial yields. Multi-K increased the resistance of grapefruit trees to salinity-induced stress by a factor of nearly two versus the value cited by Maas (3.40 vs. 1.85 dS m^{-1}, respectively).

The greenhouse tomatoes experiment shows even further, that the addition of Multi-K at a rate of 1/25 (M/M) of the concentration of the NaCl used for irrigation could reverse the salinity consequences and improve plants performances over the control. Here, too, the plants performed very well at elevated EC values of 7.5 dS m^{-1} versus nominal threshold of 2.5 dS m^{-1} determined by Maas.

The greenhouse cabbage and lettuce experiments similarly show that these crops can endure high EC values as long as their N & K nutrition is optimal. EC values of 6 dS m^{-1} and above do not necessarily result in yield drop although normal threshold was conventionally believed to be 1.8 and 1.3 dS m^{-1} for these crops, respectively (Maas). It was shown again that constant Multi-K at 5 mM can reverse the severe stresses resulting from NaCl present at a concentration an order of magnitude higher.

The general model put forward by Ben-Asher *et al*. appears to perfectly explain the salinity-induced phenomena described for all crops noted in this paper. At normal, non-saline conditions, K cation is a transportation aid facilitating the uptake of nitrate anion from soil solution into the plant roots. The nitrate is used for production of proteins. The K cation then becomes a transportation platform facilitating the movement of malate anion from the foliage to the roots, where it is used as an energy source for their functioning. When chloride prevails in the soil solution, it competes with the nitrate and is uptaken at high rates, directly related to its concentration. K cation then facilitates its uptake but chloride cannot be used, of course, as a raw material in the production of proteins. Proteins production is seriously damaged and the chloride is precipitated in leaf tips, producing typical tip-burns. Malate movement to the roots is not impaired. When sodium is excessive in the soil solution it competes with the potassium and is taken up in high rates, directly related to its concentration. This uptake facilitates the concurrent uptake of the nitrate, but is unable to assist in the transportation of the malate to the roots, and they are seriously undernourished. This, in turn, negatively affects the water-, mineral- and physiological status of the entire plant.

The general conclusion from all these cases is that the constant application of Multi-K at 2-10 mM in the irrigation / fertigation solution can counteract the deleterious effects of the chloride and the sodium in plant metabolism. The most important advantage of Multi-K versus many other fertilizers is that its contribution to salinity buildup is negligible. Both K and nitrate, which are the building blocks of this fertilizer, are macronutrients, and therefore, they are taken up in large rates while non-nutrient residues are not left in the soil.

References

Bar, Y., *et al*. 1997. Relationship between chloride and nitrate and its effect on growth and mineral composition of avocado and citrus plants. *J. of Plant Nutr*. 20: 715-731.

Ben-Asher, J. *et al*. 1997. K uptake by root system grown in saline soil: A conceptual model and experimental results. Johnston, A.E., (Editor) Food security in the WANA region, the essential need for balanced fertilization. International Potash Institute. Basel, Switzerland. 360-369.

Benzioni, A., *et al*. 1971. Nitrate uptake by roots as regulated by nitrate reduction products of the shoot. *Physiol. Plant*. 24:288-290.

Evans, H.J. *et al*. 1966. Role of mineral elements with emphasis on the univalent cations. Ann. Rev. *Plant Physiol*. 17: 47-77.

Feigin, A. 1985. Fertilization management of crops irrigated with saline water. Pl. Soil 82: 285-299.

Feigin, A. *et al*. 1991. Combined effects of KNO_3 and salinity on yield and chemical composition of lettuce and Chinese cabbage. Irrig. Sci. 12:223-230.

Hepaksoy, S. *et al*. 1999. The effect of potassium fertilization and rootstock on leaf sodium content of satsuma mandarins under saline condition. Hagin, J. and Johnston, A.E., (Editor) Nutrient management under salinity and water stress. Technion- Israel Institute of Technology, Haifa, Israel. 89- 96.

Imas, P. *et al*. 1995. Yield and water use efficiency of sweet corn grown in solution culture as affected by KNO_3 and salinity levels. Acta Hort. 401: 301-308.

Kafkafi, U. *et al*. 1971. Effect of potassium nitrate and ammonium nitrate on the growth, cation uptake and water requirement of tomato grown in sand soil culture. *Israel J. Agric. Res*. 21:1330

Kafkafi, U. *et al*. 1982. Chloride interaction with nitrate and phosphate nutrition in tomato. *J. Plant Nutr*. 5: 1369-1385.

Levy, Y. *et al*. 2000. Field screening of citrus rootstocks using trickle linear salinity gradient. Acta Hort. 511:197-203.

Maas, E.V. 1986. Salt tolerance of plants. Appl. Agric. Res. 1: 12-26.

Nitsos, R.E. *et al*. (1969) Effects of univalent cations on the activity of particulate starch synthetase. *Plant Physiol*. 44: 1260-1266.

Satti, S.M. *et al*. 1994. Effect of increasing potassium levels for alleviating sodium chloride stress on the growth and yield of tomatoes. *Commun. Soil Sci. Plant Anal.* 25: 2807-2823.

Silberbush, M. *et al*.1988. Response of peanuts grown in saline nutrient solution to potassium nitrate. J. Plant Physiol. 132: 229-233.

Taban, S. *et al*. 1999. Effects of potassium on macroelements distribution in maize plants grown under salt stress. Hagin, J. and Johnston, A.E., (Editor) Nutrient management under salinity and water stress. Technion- Israel Institute of Technology, Haifa, Israel. 215- 222.

Figure 1: The effect of salinity and Multi-K on the yield of sweet corn.

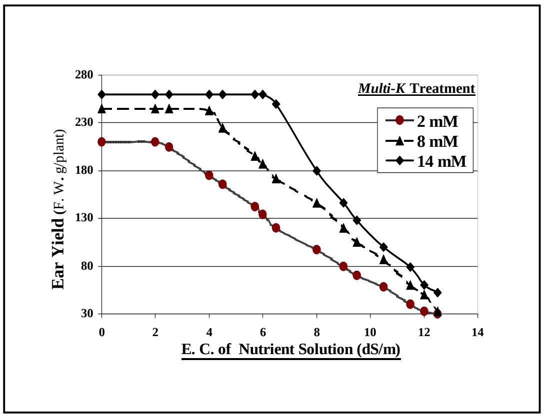


Figure 2: The effect of salinity and Multi-K* on chloride content of grapefruit leaves.

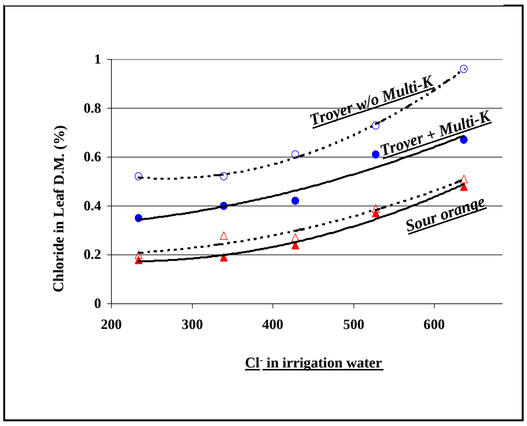


Figure 3: The effect of salinity and Multi-K* on Na content of grapefruit leaves.

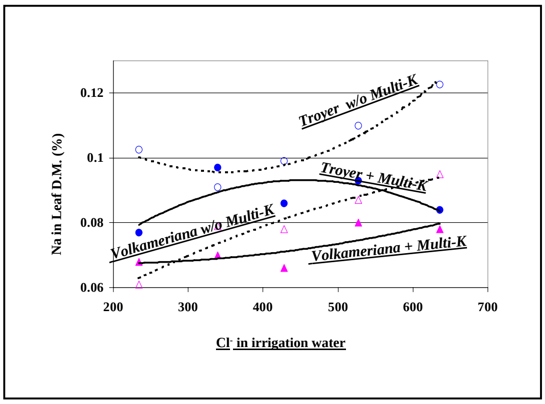
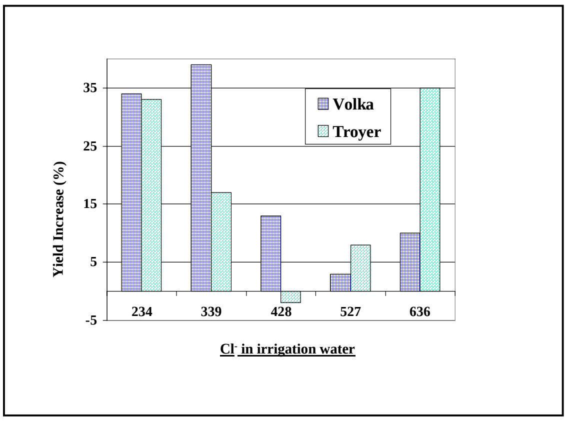


Figure 4: The effect of salinity and Multi-K* on the yield of grapefruit trees.



*Multi-K was applied at constant 200 ppm in the irrigation water.

Figure 5: The effect of salinity and Multi-K on vegetative parameters and fruit size in greenhouse tomatoes.

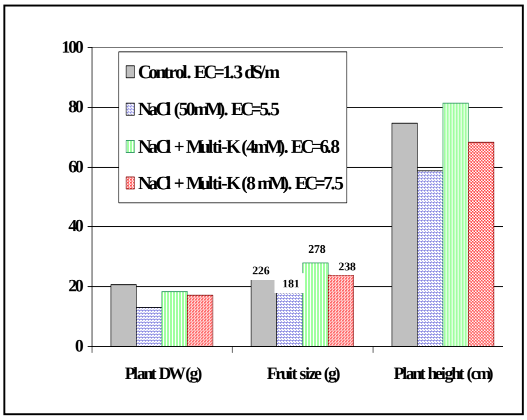


Figure 6: The effect of salinity and Multi-K on foliar K, flowering and fruit-set rate in greenhouse tomatoes.

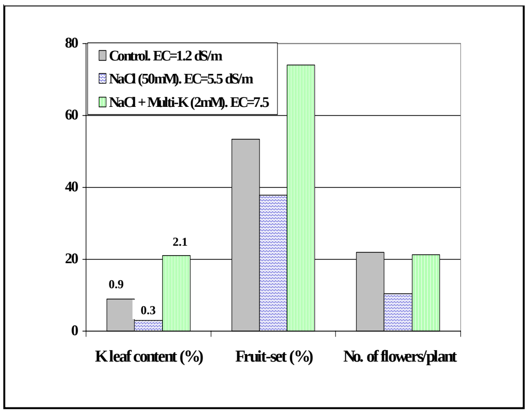


Figure 7: The effect of salinity and Multi-K on the yield of greenhouse- cabbage (cv. *Kazumi*).

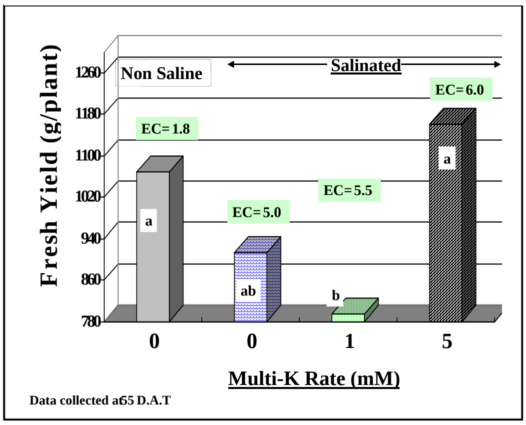


Figure 8: The effect of salinity and Multi-K on the yield of greenhouse- lettuce (cv. *Salinas*).

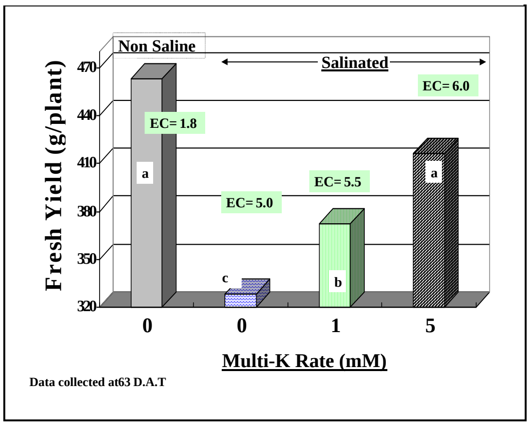


Table 1: The effect Multi-K on leaf composition of greenhouse- lettuce (cv. *Salinas*) under salinity conditions.

EC ($dS\ m^{-1}$)	Multi-K (mM)	Leaf composition			
		K	Kjeldhal-N	Na	Cl
7.25	1	1.10	3.20	0.204	0.43
7.75	5	1.13	3.36	0.191	0.54
8.30	10	1.18	3.42	0.161	0.41