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Changes of Some Macro- and Micronutrients Accumulations of Strawberries Plants (*Fragaria* × *ananassa* Dutch L.) Under Salt Stress

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In this study, gloria and kabarla strawberry varieties plants are taken for trial at solid medium culture. During the development, Hoaglan solution is added salt (NaCl) doses of 0 (control), 500, 1000,1500 mg L^{-1}. At the end of the trial, all plant parts above the soil level (aerial parts) are used for the determination of macro (N, P, K, Ca, Mg) and micro (Mn, Zn, Cu, Fe, B) elements. At the analysis done, it was determined that both of the varieties are affected from the salt stress and the accumulation levels change according to the salt doses. It was observed that the kabarla variety with the development characteristics is more tolerable to salt stress when compared with the gloria variety. It was observed that the salt applications on kabarla variety caused an increase in the accumulation of N, Ca and Mn and the accumulation of other elements led to a decrease. In the gloria variety, the increasing salt doses led to a decrease in the accumulation of all the elements whereas at the elements Zn, Fe and B in the 500 mg L^{-1} application which is the lowest water dose, an increase with respect to the control was determined. In the gloria variety, increase of Zn, Fe and B at 500 mg mg L^{-1} salt dose turned to a decrease again after the increase in the following doses.

Key Words: Nutrients, Accumulations, Strawberries, Salt stress.

INTRODUCTION

Soil salinity is a significant factor limiting the efficiency. It is stated that world's 20 % of the areas at which agricultural activities are carried on and 50 % of the areas at which there is yield production are under salt stress[1]. Particularly, in the arid and semi arid regions, it is one of the most important stress factors that restrict the plant development and production[2]. The salt harm has a quite complex effect on the plants. In addition, it is known that it leads to ion imbalances, nutrition disorders, deformations in stoma movements, interruptions in photosynthesis and problems at some other physiological events[3,4]. It was determined that different plants react differently under the same salty conditions and it was determined that these reactions are limited within the measures allowed by the plant genetics[5].

Studies to determine the effect of salt stress on the intake of nutrition elements are limited. In the studies, it was determined that the macro elements are affected more than the micro elements from salt stress[6,7]. Although there has been studies on the nutrition elements intake of strawberry plants which develop under normal conditions[8,9], the number of studies on the food intake of strawberry plants under the salty conditions are quite low. In the study carried out by Turhan and Eris[10] on camarosa and tioga varieties, it was determined that the salt applications were not effective on the Cu content. However, it was found that the Fe and Mn content increased. In the study carried out with wheat and rice, it was determined that the Zn, Cu and Mn content increased with the application of salt[6], at marrows, in the same way, the increasing salt doses had increased the Fe, Mn and Zn accumulation at the leaves. As seen in the studies performed, generally, it has been found that the increasing salt doses have an increasing effect on the micro elements however this situation can change according to the plant species and cultivars.

In the classifications, strawberry plant takes part in the most sensitive classes[11]. The limits of the harm caused by the salt stress on the strawberry plant are determined by genetic characteristics[12] and existing salt type and other environmental conditions around the root region[13,14]. Although some studies to determine the effect of salt stress has been carried out in previous years, detailed studies on intake and accumulation of nutrition materials has not been reported yet. This study has been carried out in order to determine the salt stress effect on macro and micro nutrition elements intake.

EXPERIMENTAL

Experimental conditions and treatments: The study was carried out in Plants Physiology Laboratories, Horticulture Department, Agricultural Faculty, Yüzüncü Yil University. The experiment was executed in the climatic room, which its temperature and lightening period may be set up. The climatic room was arranged in a way that day/night temperature was 22/18 ºC, day length was 16 h and humidity was 65-70 %. A cold white fluorescent lamp with 280 µmol m^2 s^{-1} was employed as light source. Both plants were planted in pots containing 1 L sterile pumice. The plants were feed by adding Hoagland nutrient solution[15] to the pots and it was supplied when required. Flower buds, which develop at early stages of plant's growth, were not allowed to grow and were cut off. At the initial stage, salt was not added to nutrient solution and salt applications were started once the plantlets had identical conditions after 30 d growth period. After this period, the plantlets had 4 or 5 leaves.

In the experiment, the salt concentrations of 500, 1000 and 1500 mg/L salt were applied. Salt was applied by adding it to Hoagland nutrient solution and each time when the plants were supplied with the nutrient solution. In case of control plants, salt was not applied and they were supplied by normal Hoagland solution.

Cultivars: In the experiment, frigo plants of kabarla and gloria cultivars were employed. General characteristics of strawberry cultivars are as the following:

Kabarla: It is a day-neutral cultivar. Its other name is Redlands Kabarla. It was obtained by hybridization of Early Sweet and Selva cultivars in Australia. It is a cultivar, which gives fruits in high amounts and high quality at early stage plantations. The fruit has a moderate size and is hard.

Gloria: It is a short-day cultivar. It is known as 'Cal Gianat 4' cultivar in USA and as Gloria in Europe and Israel. It has a tolerance to leaf, fruit and soil diseases. It gives quite well-shaped fruits and can give fruits for a long period. Fruit size is quite well during harvest period.

Analyses: After 30 d starting the salt application, all plant parts above the soil level (aerial plant parts) were taken for analysis. After the aerial parts of plants have been collected, they were dried at 65 ºC for 48 h and then grinded. In these samples, analysis was done using nitrogen by Kjeldahl method, phosphorus by spectrophotometer, potassium, calcium, magnesium flame photometer and iron, manganese, zinc, copper and boron by atomic absorption spectrophotometer[16].

Statistical analyses: The study was executed according to random trial pattern in 3 replicates and 10 plants (10 pots) in each replicate. The results of the study were resulted by making statistical analyses according to Duncan's multiple comparison method. The letter was used in case the variances were not homogeneously distributed. The 5 % probability level was accepted to indicate significances.

RESULTS AND DISCUSSION

Macronutrient elements: The changes in the macronutrient elements (N, P, K, Ca and Mg) accumulations of the gloria and kabarla strawberry varieties developed under different salt applications are given in Fig. 1.

At the nitrogen in gloria variety, depending on the salt doses, it has demonstrated a continuous decrease. The nitrogen level which is 2.23 % in the control application has decreased to 1.8, 1.75 and 1.45 % values at 500, 1000 and 1500 mg L^{-1} salt applications, respectively. The increase of nitrogen amount which is observed at the gloria variety was not observed at the kabarla variety. It was determined that, in the kabarla variety plants, the salt applications has caused an increase in the nitrogen accumulation when compared to the control plants. A partial decrease is observed at the lowest dose application of 1500 mg L^{-1} with respect to the 500 and 1000 mg L^{-1} applications. It was also stated that this decrease is significantly important.

It was stated that, at both of the gloria and kabarla varieties the phosphorus level decreased depending on the salt applications. In the 500 mg L^{-1} which is the lowest dose in the gloria variety, there occurred a slight increase at the phosphorus level. However, at the 1000 and 1500 mg L^{-1} applications, a decrease in the phosphorus levels was seen. In the kabarla variety, an unsteady change was determined at the phosphorus level in the salt applications. In addition to this, at all the salt applications, low values according to the control. The phosphorus accumulation determined as 0.86 % level in the control application, was obtained at the level of 0.79, 0.83 and 0.81 % at, 500, 1000 and 1500 mg L^{-1} salt applications, respectively.

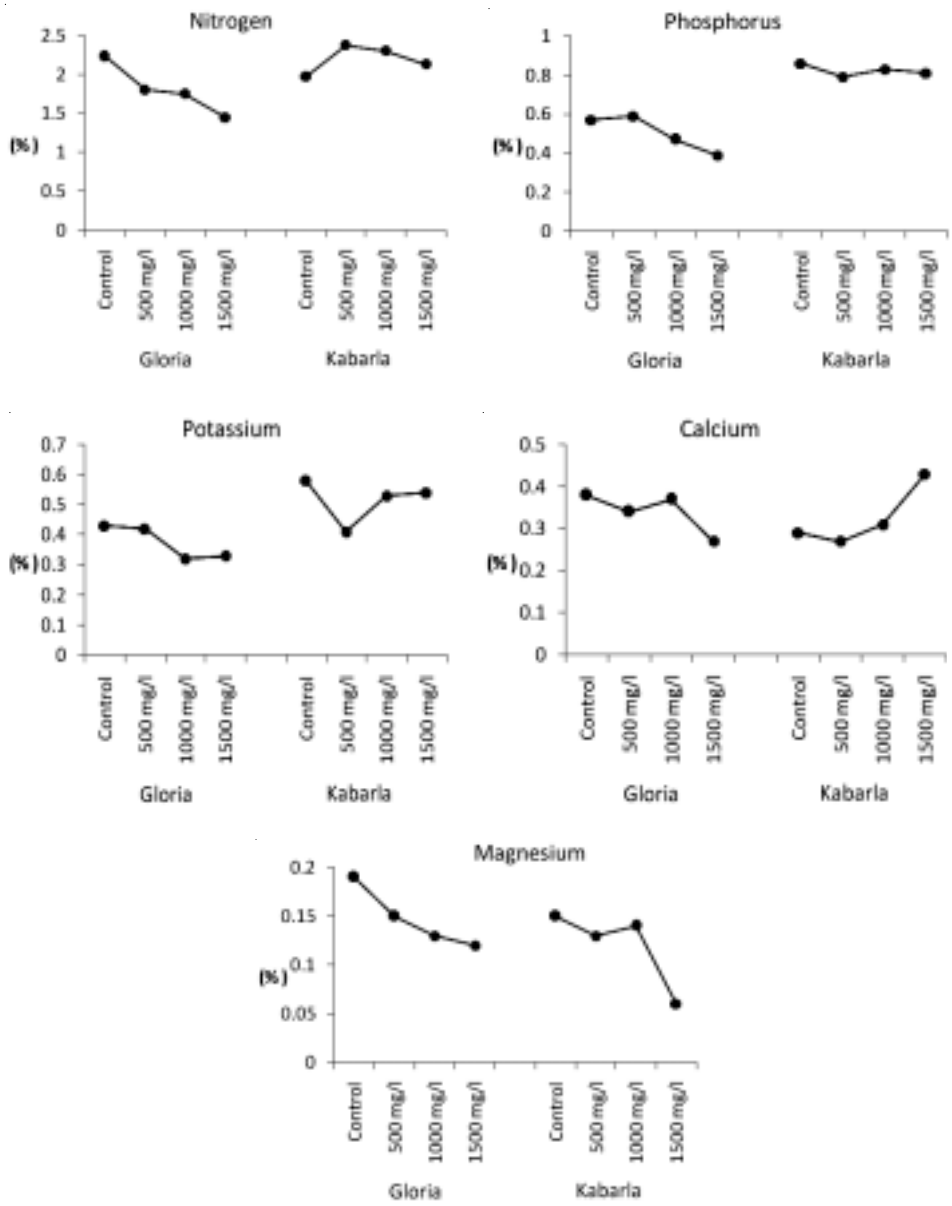

Fig. 1. Changes of some macronutrient accumulations (N, P, K, Ca ve Mg) of gloria and kabarla strawberry cultivars under salt (NaCl) stress

It was observed that the salt doses have caused significant changes at both of the varieties on the potassium accumulations. In the gloria variety, the potassium accumulation has decreased depending on the salt applications. Potassium accumulation which is 0.43 % at 500 mg L^{-1} at control plants has stayed at 0.42 % at 500 mg L^{-1} and has decreased to 0.32 % level at 1000 mg L^{-1} salt application. At the 1500 mg L^{-1}

salt application, potassium accumulation almost equal to the 1000 mg L^{-1} application (0.33 %) was determined. In the kabarla variety, depending on the salt doses, the change in the potassium accumulation has possessed a fluctuating appearance. With respect to the control plants (0.58 %), an apparent decrease (0.41 %) at the lowest level of 500 mg L^{-1} salt application was determined and at the following applications, again an increase was determined.

The calcium accumulation levels, have been determined at quite different levels for the gloria and kabarla varieties. In contrast to the decrease at the highest salt dose of 1500 mg L^{-1} application at gloria variety, an apparent increase has occurred at the kabarla variety. Such different results should be related to the variety characteristics of the strawberries plants. Generally, high salt dose is effective on calcium accumulation. The difference between the averages is also found significant statistically.

It was found that the magnesium accumulation decreased continuously depending on the increase in the salt doses. This decrease has been seen apparently both at the gloria and kabarla varieties. At the gloria variety which has 0.19 % magnesium accumulation at the control plants, magnesium accumulations of 0.15, 0.13, 0.12 % magnesium levels were determined at 500, 1000 and 1500 mg L^{-1} applications, respectively. At the control plants of kabarla variety, the magnesium accumulation value, which is obtained as 15 %, was obtained as 0.13, 0.14, 0.06 %, at 500, 1000 and 1500 mg L^{-1} salt applications.

It is known that NaCl stress leads to macro element deficiencies at maize[17], at wheat and barley[18] and tomato[19]. Also in this study, it was generally determined that the macro elements decrease depending on the salt doses. However, the change in the nitrogen and calcium amount at kabarla variety occurs in increasing direction. In a study carried with elsanta and korona varieties[20], the increase in calcium and magnesium accumulation is only determined at korona variety. However, it was stated that the nitrogen, phosphorus and potassium amounts increased in both of the varieties with the salt applications. In the kabarla variety, despite the fact that an increase in calcium and magnesium is observed, in the gloria variety, with increasing salt doses, continuous decrease tendency at calcium and magnesium amounts was determined. In spite of this change observed at kabarla and gloria varieties, in the rapella variety, the effect of salt stress on the potassium, sodium, calcium and magnesium content could not be determined[21]. The study carried with the camorsa strawberry variety, an increase in sodium, chlorine, calcium and magnesium amount and decrease in potassium and phosphorus amount were determined[22].

Micronutrient elements: The changes of micronutrient elements (Mn, Zn, Cu, Fe and B) accumulations at the gloria and kabarla strawberry varieties developed under different salt applications are given in Fig. 2.

When the manganese accumulation dependent on salt doses have been investigated, decrease at the gloria variety and increase at the kabarla variety has been determined. In the kabarla variety, the manganese accumulation fluctuated with the

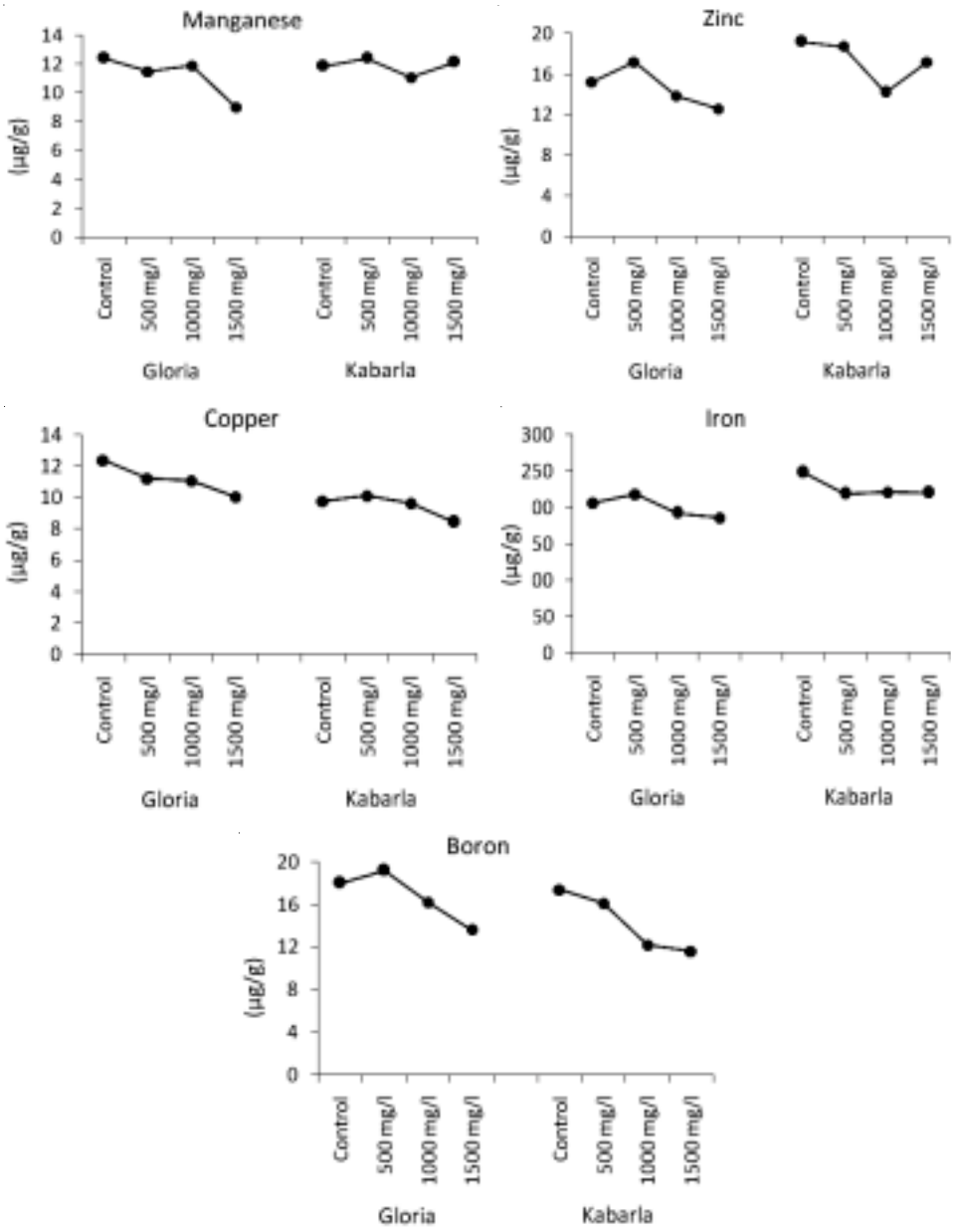

Fig. 2. Changes of some micronutrient accumulations (Mn, Zn, Cu, Fe and B) of gloria and kabarla strawberry cultivars under salt (NaCl) stress

increasing salt doses. The manganese accumulation, which is equal to 11.87 µg g^{-1}, has increased to a value of 12.42 µg g^{-1} at the 500 mg L^{-1} salt application and dropped down to the value of 11.07 µg g^{-1} at the 1000 mg L^{-1} salt application and at 1500 mg L^{-1} salt application it increased to 12.13 µg g^{-1} value.

It was determined that the effect of salt application on zinc accumulation has taken place at different levels at both of the varieties. 15.23 μg g^{-1} zinc accumulation value obtained at the control plants has shown an increase at the 500 mg L^{-1} salt application and reached to 17.21 μg g^{-1} value and at the 1000 mg L^{-1} salt application, has decreased in significant levels and decreased to 13.88 μg g^{-1}. The decrease in the zinc accumulation continued also at 1500 mg L^{-1} salt application and decreased to 12.58 μg g^{-1}. In the kabarla variety, a fluctuating change occurred. 19.21 μg g^{-1} zinc accumulation level obtained at control plants was obtained as 18.73 μg g^{-1} at 500 mg L^{-1} salt application and 14.21 μg g^{-1} at 1000 mg L application and 17.21 μg g^{-1} at 1500 mg L^{-1} application.

The effect of salt doses on the copper accumulation occurred at different levels at gloria and kabarla varieties. In the gloria variety, depending on the increasing salt doses, the copper accumulation continuously decreased. However, at the kabarla variety, at the minimum dose of 500 mg L^{-1} salt application, some increase arisen and in the following two doses, decrease has been recorded.

Iron accumulation, generally, is higher at kabarla variety when compared to the gloria variety. According to the kabarla variety control plants, all salt doses led to decrease in iron accumulation. However, a statistical difference could not be found at the iron accumulation at 500, 1000, 1500 mg L^{-1} salt applications. In the gloria variety, with respect to the iron accumulation (206.43 μg g^{-1}), the iron accumulation exposed to 500 mg L^{-1} salt application (218.03 μg g^{-1}) is obtained higher. The following salt applications led to lower iron accumulations.

The effect of salt doses on the boron accumulation, at both varieties, have taken place in the negative direction like it has happened at other elements. The 500 mg L^{-1} salt application increased the boron accumulation (19.21 μg g^{-1}) with respect to the control plant (18.03 μg g^{-1}). However, at the following applications, boron accumulation showed a continuous decline. In the kabarla variety, it was observed that all of the salt applications led to a decrease in the boron accumulation. In the control plants, the boron accumulation of 17.41 μg g^{-1} has decreased to values of 16.09, 12.18, 11.63 μg g^{-1} at 500, 1000 and 1500 mg L^{-1} salt applications respectively.

Although it has been acquainted that the micro element accumulations are affected less than the macro element accumulations[23] or has not been affected[24]. In the present study, the positive and negative affects have been observed together in the two strawberry varieties. In addition, it was determined that depending on the salt doses, some elements change in a limited level and the others change significantly. At the study carried by Turhan and Eris[10] on camarosa and tiago varieties, it was determined that the iron and manganese amounts increased at both varieties and zinc amount increased at tiago variety. In present study, under the low salt dose, in the gloria variety, increase was determined at zinc iron and boron and at kabarla study increase was determined at manganese and copper. However, it was determined that the increase in salt doses yield to a decrease in these elements. As

can be seen at various studies, the species and variety of plants developed under salt stress have a serious impact on the food material intake[25]. These impacts' being positive or negative is determined by the genetic characteristics of the species and varieties and development conditions.

Conclusion

In addition to the changes depending on varieties and salt doses, generally, it can be said that it leads to decrease in macro elements. However in the study, it has been found attention-grabbing that at the kabarla variety the developmental characteristics are more tolerable to salt when compared to gloria variety, the nitrogen and calcium accumulation increases. Although low salt doses yield to an increase at some of the micro elements, the increase in the salt doses has led to decreases.

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