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高燐 활용성 토마토의 항 염분 특성

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Salt tolerance in phosphorus efficient tomato (*Lycopersicon esculentum* Mill.)

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Abstract : To test a potential salt tolerance in phosphorus (P) efficient plants (T9 and T8), tomato seedlings were hydroponically grown in saline media. The tolerance was evaluated by comparing growth and metabolism against T5, non-P-efficient variety, at different salt concentrations: 0, 1, 5, 10 g/L. Fresh weights (FW) were measured weekly. Dry weight (DW), mineral contents, and stomatal resistance (Rs) were measured at the termination of experiment. At the lower two salt concentrations (0, 1 g/L), no significant difference was observed in terms of FW, DW, and Rs. At 5, 10 g/L of salt concentration, however, significant variation is evident: T9 and T8 outperformed T5. On the other hand, no difference was also in N, P, K, and Na contents at the corresponding salt concentration. These observations together indicate that P-efficient strain can better tolerate to salinity.

Key words : P utilization efficiency, P-deficiency, anthocyanin-free, tomato, hydroponics

List of Abbreviation
TFW: total fresh weight
DW: dry weight
FW: fresh weight
Rs: Stomatal resistance

Introduction

The soil salinity inhibits most plant varieties from maintaining their normal growth. The salinity makes it difficult for plants to obtain sufficient water from soil and high concentration of salt absorbed has a serious effect on plant cell growth, thus preventing from maintaining its normal growth on the saline soil.[1,2] Due to the soil salinity in the Yongjong Island, the Inchon International Airport complex has already been encountering significant problems with landscaping[3]. The soil salinity problem also caused a major problem in landscaping the Osaka International Airport in Japan. These problems stemmed from lack of plant species which can overcome the soil salinity. Under salt stress, plants show retarded growth especially on shoot and, thereby, lower shoot-to-root ratio.[4,5]

To cope with such salinity problems, a principal strategy might be to develop salinity tolerant plant varieties.[6] The potential salt tolerant plants can remove excessive salts from soil. Most important, the tolerant plants are essential to establishing a favorable environment which contributes to managing sustainable development for the salty soil area. Within different plant species, there is variation in the tolerance to salinity; many investigators have been greatly interested in the recognition (or screening) of such intra-specific variation.[8,9,10] This can be used as an important resource for developing a salt-tolerant line of plant species. Many studies indicate that salinity problem can be alleviated by supplementing phosphate into soil.[11,12,13,14] Under the circumstances, the present study is to investigate the salt tolerance of a series of phosphorus efficient tomato strains.[15]

To evaluate the anti-salinity potential in the different tomato strains, seedlings were hydroponically grown at different levels of salinity. The performances were evaluated in terms of visual appearance, fresh weight, dry weight, stomatal resistance, and tissue salt concentration.

Materials and Methods

Seeds of tomato varieties 80957 (T9), 80883 (T8), and 80553 (T5) were planted in a 1:1 mixture of vermiculite and perlite, and moistened as necessary with deionized water. Early in the four-leaf stage, the seedlings, selected visually for uniformity, were transplanted to hydroponic pots. The culture media were made up according to Gerloff.[8] Four levels of salinity were prepared by loading unpurified sea salt at 0, 1, 5, 10 g per liter of the hydroponic culture media.

The hydroponic culture systems were maintained in constant environment growth chambers. The growth chambers were set at 32℃ (day) and 24℃ (night) under 16 hour photoperiods with light intensity of 2400 $\mu E\ m^{-2}$. Aeration of the hydroponic solution was omitted since preliminary investigations revealed that it was not necessary. Water lost from the hydroponic pots, due to transpiration and natural evaporation, was replaced as necessary to insure that reduction in water volume did not exceed 10%. Twice per day watering was necessary in larger plants to prevent mineral salt concentration. Two weeks after the transfer into the hydroponic system, the nutrient solution was changed weekly.

The fresh weight was measured weekly. Stomatal resistance were measured using a LICOR-6200 Potable Photosynthetic System. For these measurements, three plants each from the two varieties and the different salt concentrations were randomly chosen. Sampling was made on a leaf (one at the fifth nodes from the base). Also, measurement of the rates of dark respiration and transpiration were made on the same leaves. Leaf areas, necessary for standardizing the various rate, was measured by a Bausch & Lomb Optical Area Meter.

To calculate the shoot to root ratio, the plants were cut on the top of the root system. Dry weight of leaves and root-stem complex were individually measured and summed for whole plant weight. After the measurement, mineral content each of root-stem complex and leaves was determined by employing a SOLAAR 969 Atomic Absorption Spectrometer.

(A)

(B)

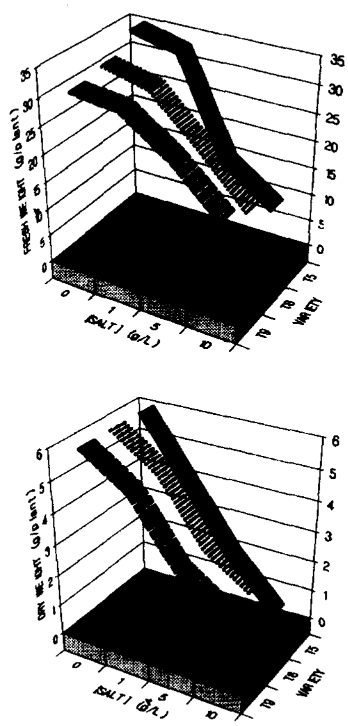

Figure 1. Fresh weight and dry weight comparison

(A) Throughout 4 week hydroponics culture, fresh weight was measured from 10 plants weekly. Each tape refers to the fresh weight at the four salt concentrations. The ends and the bending phases of each tape represent the average fresh weight measurements per plant. (B) At the termination of culture, dry weight was measured following an overnight dehydration in a forced circulation chamber.

Results

The salinity condition had a distinctive impact on the rate of fresh weight increase in both varieties. As the salinity increased in the nutrient solution, each variety showed a consistent reduction in fresh weight (FW) (Figure 1-A).

Significant differences among the three varieties were observed in FW at salt concentrations of 5 and 10 g/L after 4 weeks of hydroponic culture. T9 and T8 demonstrated greater FW than T5. It was noted that T9's FW at 5 g/L was comparable to T5's FW at 1 g/L. When the dry weight (DW) was compared, the pattern characteristic in FW comparison was also observed (Figure 1-B). At the lower salt concentrations, the three varieties did not show any significant DW difference. At the salt concentration of 5 or 10 g/L, however, both T9 and T8 exceeded T5 in DW in the culture media. The greatest DW difference was observed at 10 g/L, where T9 had an increase 137.2% more DW than T5. Between T9 and T8, T9 consistently showed a greater DW than T8 at 5 and 10 g/L of salt concentration.

The susceptibility to salinity was expressed as the absolute slope from the plot of fresh (dry) weight vs. the salt concentration. T9 had the least susceptibility to the increasing salt concentration than T5: 2.1 vs. 4.5 for FW and 1.6 vs. 4.8 for DW. When FW and DW were further analyzed at all salt concentrations, the salt tolerance of T9 and T8 was clearly shown. T9 and T8 grown at 5 g/L showed a fresh weight gain equivalent to that of T5 grown in a solution with 1 g/L. In terms of dry matter accumulation, T9 and T8's performance at 10 g/L surpassed any of T5's at 5 g/L of salt concentration.

The increasing salinity in the culture media was shown to give negative impacts on the stomatal resistance (Rs). With increasing salt concentration in culture media, the Rs decline commonly for T9, T8, and T5. Figure 2 shows that the extent of decrease, however, varies according to the leaf age and variety. In old leaves, the increasing salinity reduce the Rs for T9, T8, and T5; no statistical difference was apparent among the three varieties. In young leaves, Rs declines more rapidly than old leaves at the 5 and 10 g/L. The susceptibility to the salinity was greatly varied among T9, T8, and T5. Compared to the non-saline media, the saline media reduced stomatal resistance on T5's old leaves. Yet, T9's old leaves exhibited a significant Rs in the presence of minimal P-supply. These results indicate that T9 and T8 can better tolerate to an increased tissue salt concentration in old leaves than T5. With regard to photosynthetic rate, neither variety showed statistically significant differences at the different saline conditions (data not shown).

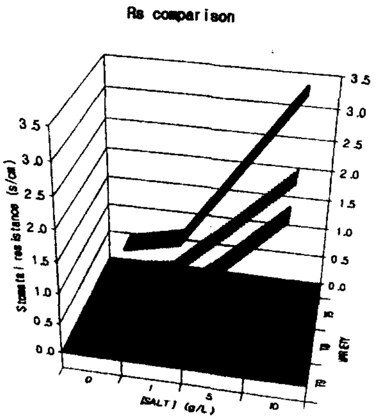

Figure 2. Stomatal resiatance comparison

The Stomatal resiatance (Rs) were determined by measuring the resistance to CO_2 diffusion with a Li-Cor measuring system (Model LI-6200) at the end of culture. Three plants were randomly chosen each for 0, 1, 5, 10 g/L.

In terms of shoot-to-root ratio, the three varieties showed a significant difference (Figure 3). All three varieties exhibited decreasing shoot/root ratios when the media salt concentration was elevated. With incremental salt concentration, T9' s shoot showed the least susceptibility. Figure 3 showed T5, the non-P-efficient strain, showed the highest sensitivity to the salt concentration increase. This observation strongly indicates that T9 and T8 are capable of maintaining its normal shoot growth in the presence of the toxic salt supply.

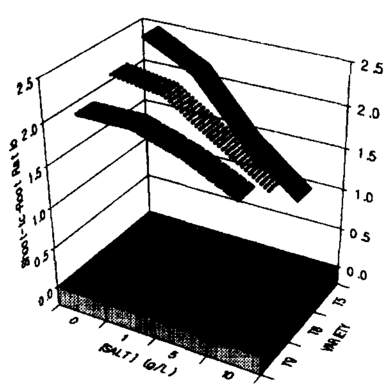

Figure 3. Shoot/Root ratio determination

Shoot/Root ratio was determined on three plants whose fresh weight ranked near the median for their group. After blotting excessive moisture on paper toweling, shoot and root were severed at the top of the root system.

Determination of tissue mineral content by ash analysis revealed that tissue salt concentration was closely correlated with the loading salt concentration: For both varieties, correlation coefficients ranged from 0.96 to 0.99 between tissue salt concentration and logarithmically transformed culture solution salt concentration. With incremental media salt concentration, the three varieties showed consistent increase in tissue Na mineral content (Figure 4). In terms of N/P/K contents, the three varieties showed similar at equivalent media salt concentration. This similar tissue P content observed among the three strains showed that P-efficient strain' s better performance was not due to its higher tissue P concentration. Instead, the similar tissue Na or P concentration, at equal exogenous salt concentration, implies that T9 and T8 could tolerate to salinity by utilizing P absorbed from the nutrient medium more efficiently.

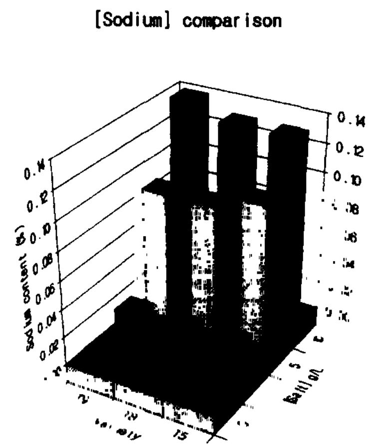

Figure 4. Tissue sodium concentration

Tissue sodium concentration was determined by ash analysis on the pool of three plants whose dry weights reside at or near the median. Tissue sodium content varied significantly ($p < 0.05$) among the media salt loadings; however, no difference was observed among the three varieties at the equivalent media salt concentration. Similarly, tissue N/P/K content insignificantly varied among the three varieties (data not shown).

Discussion

This study characterized the potential salt tolerance in P efficient strains, T9 and T8. Under the salt concentration equivalent to the toxic levels in the hydroponic solution, both T9 and T8 outperformed T5. Consistent with the known strength of P utilization efficiency (i. e., T9>T8), T9 appeared to tolerate to the salinity better than T8 at the toxic salt concentration.

The salt tolerance in T9 and T8 was evident when comparing fresh weight increase and dry matter accumulation against T5. At equal salt concentration, T9 and T8 exceeded T5. Furthermore, T9 and T8 grown at 10 g/L showed a fresh weight gain equivalent to that of T5 grown in a salt solution with 5 g/L. In terms of dry weight, T9 accumulated approximately the same dry matter at 10 g/L as T5 did at 5 g/L.

Two types of susceptibility were apparent when the FW or DW changes were compared at increasingly higher nutrient solution salt concentrations. T9 and T8 lost much less fresh and dry weight than T5 at the toxic level of salinity. Based upon its susceptibility, T9/T8 can be considered as a "non-Responder" to changes in salt concentration in the hydroponic culture solution.

The similar tissue sodium concentration observed in T9/T8 showed that its better performance at equal exogenous salt concentration was not the simple expression of its less tissue salt concentration. Instead, the similar tissue sodium concentration strongly suggests that T9/T8 could tolerate to the equivalent toxic salt concentration more efficiently.

The salt tolerance of T9 was also demonstrated in a companion study (data not shown). Three-week old seedlings from T9 and T5 were subjected to a extreme toxic conditions (20 g/L in culture media) for 2 days and transferred to a non-saline nutrient solution. When this occurred, most T5 developed severe necrosis over the lower leaves and died within ten days; whereas, most T9 recovered to a normal appearance within four days and survived. This observation implies that T9 has the capacity for a normal metabolism under its excessive internal salt content and for recovery from the toxic salt shock.

Statistical analysis on the stomatal resistance data showed a significant difference between P-efficient strains and T5. This suggests that T9/T8 can grow and function normally at the higher external salt concentration for normal growth than did T5. A negative correlation was shown between the stomatal resistance and leaf area both in salt stressed plant and normal plants. Accordingly, the overall negative correlation between the stomatal resistance and nutrient salt concentration can be explained in line with Maas and Grieve' s assertion[16], seeing that leaf area was considerably reduced in this study for both varieties under salt stressed condition.

Correlating P utilization efficiency to salt tolerance is a serious undertaking. No work have been published on the relationship between these two strengths. Factors involving P efficiency might exert a positive effect on those for salt tolerance. Otherwise, morphological factors (e. g., roots size and morphology) characteristic to the P efficient strain help plants tolerate to high salinity.[17,18,19] In any case, biochemical and molecular studies are necessary to investigate how the P-efficiency coincides with the salt tolerance in T9/T8. Currently, T9' s tolerance to high salinity is being characterized on saline media by plant tissue culture techniques. Its performance will be very crucial to determine whether its potential salt tolerance results from cellular strength under the excessive saline condition.[20,21]

Salt tolerant plants will be of great use to improve the soil salinity problem. These plants will help removing salt from soil and will constitute an essential factor for the potential development along the seaboard. Although the present study is mainly focused on vegetative growth, the P-efficient strain did show sufficiently greater performance, even with equivalent tissue salt concentration. By analyzing P-efficient strain' s growth and metabolism at various salt concentrations (adequate, moderately toxic, and toxic), this study suggests that P-efficient strains can perform better at the toxic salt concentration than a non-P-efficient strain. Further investigation is necessary to study whether salt tolerance of P-efficient strains exists in other plant species. Especially, investigation on landscape plants may contribute immediate benefits to land developing projects in the West Coast Area in Korea.

요 약

고율의 인활용성을 보이는 토마토 품종의 항염분 특성을 검증하기 위하여, 염분이 첨가된 배양액을 이용한 수경 재배를 실시하였다. 항염분성의 검증은 인산활용도가 높은 것으로 알려진 품종 (T9과 T8)의 생육을 비인산 효율성 품종인 T5의 생육과 비교하여 실시하였다. 본 실험에 이용된 염분의 농도는 0, 1, 5, 10 g/L 이다. 0, 1g/L의 염분 농도에서는 두 집단 간의 유의성이 발견되지 않았다. 그러나, 5, 10 g/L의 염분 농도에 있어서 T9과 T8의 생육은 T5와 비교하여 생물 및 건물 무게, 기공의 저항도, 지상 부 발달도 부문에 있어 유의성있게 앞선 것으로 나타났다. 반면, 나트륨, 인, 질소, 칼륨의 식물조직내의 농도는 품종간 차이가 없는 것으로 나타났다. 본 연구결과는 고 인 활용성 토마토 품종은 비 인효율성 품종에 비해 염분에 대한 저항성이 높은 것으로 판단된다.

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