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Changes in Nutrient Absorption during Growth of Cherry Tomato in Hydroponic Culture

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Abstract

To investigate quantitatively the change in nutrient absorption during growth, a cultivar of cherry tomato was grown in nutrient solution by hydroponic culture. To measure nutrient absorption, components and quantities of cations and anions in nutrient solution were separately analyzed by ion chromatography at regular intervals. Absorption of Cl^- and SO_4^{2-} little varied throughout all growth stage in condition of complete nutrient solution, while that of NO_3^-, PO_4^{3-}, Na^+, K^+ and NH_4^+ increased throughout the hyperthophic stage of fruits to harvesting stage. Though it is known that nitrogen is absorbed in the form of NO_3^- and NH_4^+ at around pH 7 in tomatoes, in the present study it was absorbed in the form of NO_3^-. Because the activity of NO_3^- reducing enzyme is dependent on lighting conditions, the result of this study support the conclusion that more NO_3^- is absorbed than NH_4^+ under strong lighting.

Keywords: Hydroponic Culture, Ion Chromatography, Nutrient Absorption, Tomato

Introduction

Plant growth and development is generally affected by its genotype, environment and the interaction of these factors. One of the main environmental factors to which plants respond is mineral nutrient. Hydroponic culture is suitable in order to investigate about plant nutrition[1). Studies on the absorption of mineral nutrient in plant examined mainly in the field of agricultural science suggest that the absorption curves of nutrient elements differ among species of plant and during growth stage[2). However, there is few studies on absorption of anion, especially Cl^- and SO_4^{2-}, and it is remained as a problem in hydroponic culture. In the present study, the changes of nutrient absorption during all growing stages of cherry tomato, which was the most popular plant for hydroponic culture, were measured quantitatively by ion chromatography.

Materials and Methods

(1) Plant culture

Seedlings of 30 day-old of cherry tomato (*Lycopersicon esculentum* var. *cerasiforme* cv. Mini carol) grown in a greenhouse of the Naruto University of Education was used as material. Four seedlings transplanted to a culture box (18×60×18 cm) with nutrient solution of 10 l for hydroponic culture. The system of hydroponic culture is shown in Fig. 1. The nutrient solution was aerated by continuous bubbling.

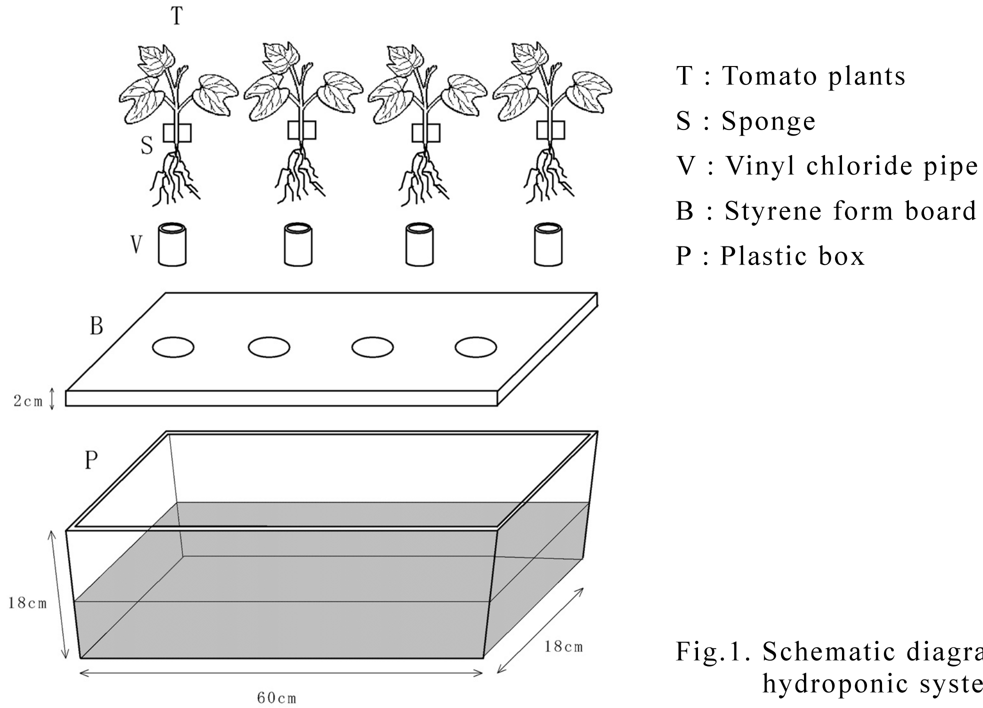

Fig.1. Schematic diagram of the hydroponic system.

(2) Experimental solutions

Macro- and micronutrient solution used in this study were prepared as a stock solution with the concentration of 1000-folds separately as shown in Table 1.

(3) Measurements of nutrient absorption

Absorption of each component was estimated as a difference of content in nutrient solution between before and after cultivation. Sampling of nutrient solutions was made at 14, 20, 27, 34, 41 and 49 days after transplanting, when nutrient solutions were exchanged. After the addition of deionized water until the level of beginning of cultivation, about 30 ml of nutrient solution was sampled, vacuum filtrated with a 0.2 μm membrane filter of cellulose nitrate (Toyo Roshi Co., Japan) and stocked in a refrigerator at 4℃. Before the filtration, pH and electric conductivity (EC) were measured with a portable pH meter, Twin-pH B-112(Horiba Co., Japan), respectively. After the dilution of sample solutions in 10-folds with distilled water the content of anions and cations were analyzed separately with an ion chromatography. Anions were analyzed with a system 2000i (Dionex Co., U.S.A) using a separator column (HOIC-ASA4) with one guard column (HPIC-AGA4) and anion fiber suppressor (AFS-1).

Table 1. Chemical compositions of stock solutions

Stock solutions	Mineral nutrient	Components	g/l
A	NH_4NO_3	NH_4^+ ,NO_3^-	71.4
B	Na_2HPO_4	Na^+, PO_4^{3-}	117.4
C	K_2SO_4	K^+, SO_4^{2-}	36.6
D	$MgSO_4 \cdot 7H_2O$	Mg^{2+},SO_4^{2-}	91.2
	$MnSO_4 \cdot 4H_2O$	Mn^{2+},SO_4^{2-}	4.2
	H_3BO_3	B^{3+}	2.8
E	$CaCl_2 \cdot 2H_2O$	Ca^{2+},Cl^-	26
F	$FeC_6H_5O_7$	Fe^{3+}	32

After applying 2.5 ml of sample solution, the eluent containing 2 mM Na_2CO_3 and 1.5 mM $NaHCO_3$ was flowed with a rate of 1.5 ml·min^{-1} at 25 ℃. The suppressor regenerant was 12.5 mM H_2SO_4. Detector sensitivity was 10 μs scale. Cations were analyzed with HIC-6A (Shimazu Co., Japan), using a separator column (IC-C1) with one guard column (IG-GC1). After applying 10 μl of sample solution, eluent containing 500 mM HNO_3 was flowed with a rate of 1. 5 ml·min^{-1} at 40℃. The results of chromatographic separation were recorded with a strip chart recorder, Chromatopack C-R3A (Shimazu Co., Japan). The concentration of each ion was determined by the comparison of the area of each peak and calibration curves of standard solution. The concentration of nutrient solution was decupled and subtracted from that of calibration curves of standard solution arithmetically.

Results and Discussion

Figs 2 and 3 show the changes of pH and EC during hydroponic culture of cherry tomato. The observed values of pH and EC decreased as the days in cultivation increase. Figs 4 and 5 show the absorption of mineral nutrients during all growth stages of hydroponic culture under the full nutrient condition. Mineral nutrient in the nutrient solution generally affected the growth and development of tomato. The daily consumption of water and nutrient absorption by plants were related to their growth and development. Water uptake was lower at the young stage but when the plant reached the reproductive stage, water consumption was dramatically increased. The absorption of Cl^- and SO_4^{2-} was a little during all growth stage, while that of NO_3^-, Na^+ and K^+ were increased during the hyperthophic stage of fruits to harvesting stage. Bowling [3] reported that the absorption of K^+ was passive and proportioned to absorption of water. The result of this study also suggested that the absorption of Na^+ and $K^+$was concerned with the absorption of water involving transpiration at high temperature, besides the accumulation in fruits. Ikeda[4] reported that tomato absorbed nitrogen as the both form of NO_3^- and NH_4^+. Though it is known that nitrogen is absorbed in the form of NO_3^- and NH_4^+ at around pH 7 in tomatoes[5], in the present study it was absorbed in the form of NO_3^-. Because the activity of NO_3^-reducing enzyme is dependent on lighting conditions[4], the result of this study support the conclusion that more NO_3^- is absorbed than NH_4^+ under strong lighting.

In the present study, NO_3^- was more absorbed than NH_4^+ during all growth stages. This suggests that in higher condition of light intensity NO_3^- is more advantageous as a nitrogen source than NH_4^+, because NO_3^- reduction is more active in such condition [6]. Generally, the absorption curve of nutrients varied among plants, seasons, temperatures, solar radiations or growth stages. Therefore, it is necessary to estimate absorption curves under the various conditions. In the present study, air was not supplied into nutrient solution during cultivation, therefore further investigations from a view-point of aeration to roots are also necessary.

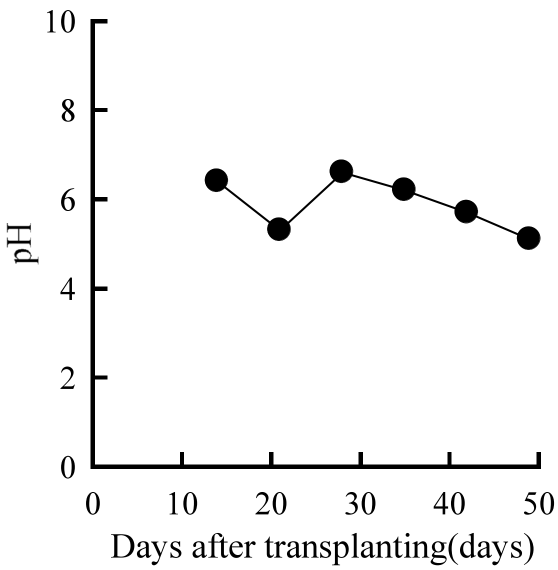

Fig.2. Changes of pH during hydroponic cultivation of cherry tomato(●:pH).

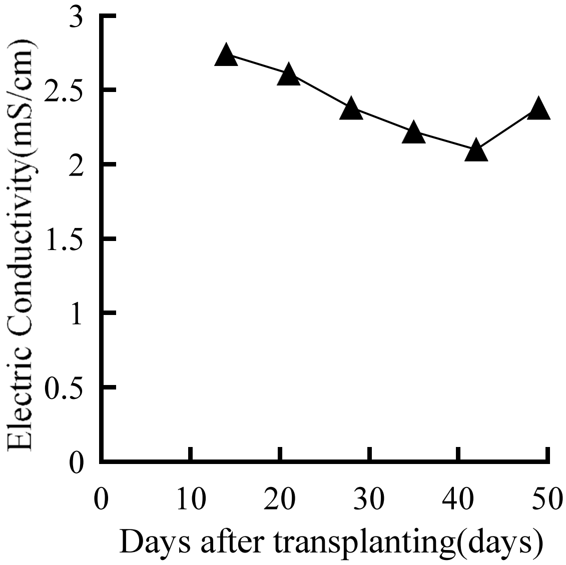

Fig.3. Changes of EC during hydroponic cultivation of cherry tomato(▲:EC).

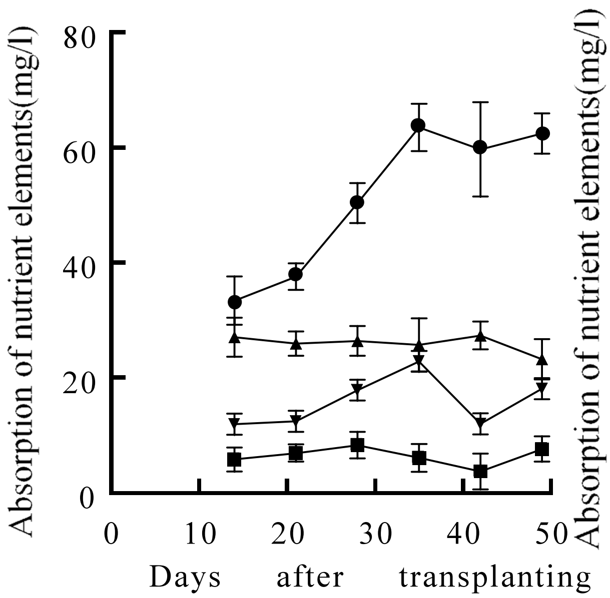

Fig.4. Absorption of anions during hydroponic cultivation of cherry tomato(●: NO_3^-, ▲: SO_4^{2-}, ▼: PO_4^{3-}, ■: Cl^-). Each value is the mean ±standard error of four replicates.

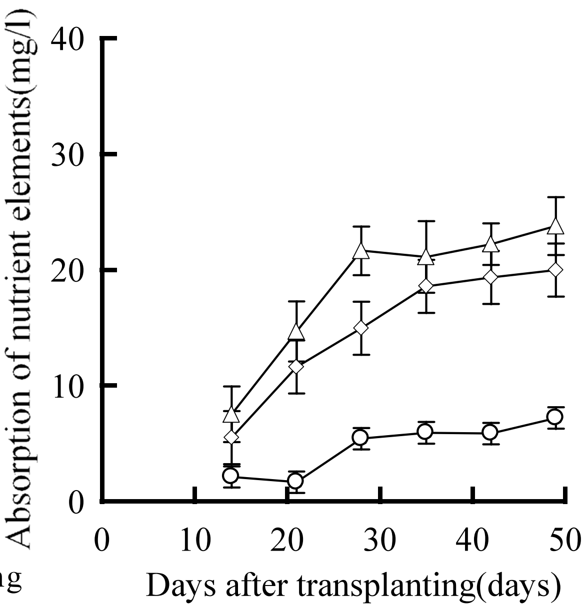

Fig.5. Absorption of cations during hydroponic cultivation of cherry tomato(△: NH_4^+, ◇: K^+, ○: Na^+). Each value is the mean ±standard error of four replicates.

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