Diurnal Changes of the Exudation Rate and the Mineral Concentration in Xylem Sap after Decapitation of Grafted and Non-grafted Cucumbers¹

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Summary

The xylem sap in cucumbers (*Cucumis sativus* L.) which were or were not grafted onto figleaf gourd (*Cucurbita ficifolia* Bouché) was collected after decapitation from the cut end of the stems hourly. The exudation rate was highest in the first one hour collection regardless of grafting, and then decreased rapidly with time. However, there was a diurnal change in the exudation rate with the maxima occurring at 1:00 to 3:00 PM and the minima at 7:00 to 8:00 AM, irrespective of decapitation time. The grafted cucumbers were smaller in amplitude than the non-grafted ones.

The rate of xylem exudation and the concentrations of NO₃-N, P, Ca and Mg in the first one hour exudate were higher in the grafted cucumbers than in the non-grafted ones. Only the K concentration was higher in the non-grafted cucumbers. The mineral concentration in the exudate changed remarkably with time after decapitation; the NO₃-N, K and Ca concentrations decreased and the P concentration increased rapidly for the first several hours. The Mg concentration scarcely changed. Thereafter, the NO₃-N and K concentrations of the exudate in the grafted cucumbers fell below the NO₃-N and K concentrations in the nutrient solution, while in the non-grafted cucumbers the former was kept always above the latter.

From these results, the grafted cucumbers were considered to be superior to the non-grafted ones, in water uptake and nutrient absorption except for K and also to depend more intensely in NO₃-N and K absorptions on some metabolites from the upper parts of the plants.

Introduction

Many kinds of fruit vegetables in Cucurbitaceae are often grafted not only to give them the advantage of disease-resistance but also to promote their growth at relatively low temperatures. Cucumber plants of the slicy type with white spines are usually grafted onto figleaf gourd plants. The grafted cucumbers are different from non-grafted ones in some physiological and ecological responses (1, 3, 5, 7), perhaps due to the ability of water uptake and mineral absorption of their figleaf gourd roots. The authors (5) have previously reported that grafted cucumbers were different from non-grafted ones in the rate of xylem exudation and the concentrations of mineral elements in the exudate, which changed with

three different sampling times of 1, 5 and 24 hours after decapitation.

The present study was carried out to obtain further information on such differences between grafted and non-grafted cucumbers by analyzing the xylem sap collected with fraction collector every hour over a period of 48 hours after decapitation.

Materials and Methods

Cucumber plants (cv. Tokiwa No. 3, p-type) and figleaf gourd plants were germinated in vermiculite in late September and grown in a vinyl-covered greenhouse. Two weeks after emergence, half of the cucumber plants were approach-grafted onto the figleaf gourd plants and transplanted into plastic pots filled with gravel and grown in gravel culture. Ten

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Fig. 1. Changes with time after decapitation in the exudation rate of grafted and non-grafted cucumbers.

Open symbols represent the nutrient solution temperatures, closed symbols the exudation rates.

Date of stem cutting : G_1 : Nov. 22 NG_1 : Nov. 25 G_2 : Nov. 27 NG_2 : Nov. 30

days after the grafting, the hypocotyls of the grafted cucumbers were cut off. Uniform seedlings of grafted and non-grafted cucumbers were transferred into water culture and grown in the standard nutrient solution formulated by Hort. Res. Sta. The solution of 300 litres was circulated for 15 minutes at intervals of 15 minutes and renewed 5 days before the stem cutting was done to sample the xylem sap. The nutrient solution was kept at pH 5.9–6.8 and EC 1.8–2.4 mmho/cm. In late November, the plants were de-topped 15 cm above the uppermost roots at different times of the day and the exudates from the cut end of stems were collected hourly with a fraction collector. At the time of stem

cutting, a small quantity of the nutrient solution was taken for mineral analysis. During the period of sap collection, the nutrient solution temperature was recorded every hour by a meteorological apparatus for agriculture (Iio Electric Co. Ltd). The exudates were stored at -20°C until analysis. They were analyzed for $\text{NO}_3\text{-N}$ by a nitrate electrode (Orion Research, Model 810 A), for P using the ammonium molybdate procedure and for K, Ca and Mg with an atomic absorption spectrometer (Hitachi, Type 518).

Results

Fig. 1 shows the change with time of the exudation rate in grafted and non-grafted

Fig. 2. Changes of $\text{NO}_3\text{-N}$ and P concentration in the exudate with time after decapitation. Open symbols represent measurements from the grafted cucumbers, and closed symbols from the non-grafted ones. Dotted lines indicate the concentrations of respective elements in the nutrient solution. G_1 , G_2 , NG_1 and NG_2 represent the same plants as in Fig. 1.

cucumbers. The highest exudation rate was detected in the first one hour collection, and it was higher in the grafted cucumbers than in the non-grafted ones. There was a pronounced diurnal change with the maxima occurring at 1:00 to 3:00 PM and the minima at 7:00 to 8:00 AM, irrespective of decapitation time. The grafted cucumbers were smaller in amplitude than the non-grafted ones. Similar results were obtained in numerous experiments repeated with grafted and non-grafted cucumbers. During the period of sap collection, the nutrient solution temperature was found between 12°C and 22°C . It increased gradually from 8:00 AM, and reached a maximum at 4:00 PM.

The concentration of $\text{NO}_3\text{-N}$ in xylem sap collected for one hour immediately after decapitation was higher in the grafted cucumbers than in the non-grafted ones; being about 400 ppm in the former and about 300 ppm in the latter, whereas the $\text{NO}_3\text{-N}$ concentration in the nutrient solution was 160 ppm. How-

ever the $\text{NO}_3\text{-N}$ concentration in the exudate decreased rapidly with time regardless of grafting and reached near to the $\text{NO}_3\text{-N}$ concentration in the nutrient solution with in 8 hours after decapitation. Further with time, the $\text{NO}_3\text{-N}$ concentration in the grafted cucumbers decreased below that in the nutrient solution, whereas in the non-grafted cucumbers the $\text{NO}_3\text{-N}$ concentration was always above that in the nutrient solution and showed a tendency of diurnal change, having a maximum at about 3:00 PM (Fig. 2).

The concentration of P was far higher in the exudate than in the nutrient solution. The P concentration for the first one hour exudate was 1.5 times higher in the grafted cucumbers than in the non-grafted ones. The P concentration in the grafted cucumbers increased rapidly with time. Five hours after decapitation, it reached 1.5 to 2.0 times higher than one hour after decapitation and the high concentration was kept for about 5 hours. Thereafter it decreased rapidly, but even after

Fig. 3. Changes of Mg, Ca and K concentrations in the exudate with time after decapitation. Symbols are the same as in Fig. 2.

48 hours it was kept far higher than the P concentration in the nutrient solution.

The concentration of K for the first one hour exudate was higher in the non-grafted cucumbers than in the grafted ones, whereas the concentrations of Ca and Mg were lower in the former. The K and Ca concentrations decreased gradually with time after decapitation in the non-grafted cucumbers, but in the grafted ones they decreased rapidly. In particular, the K concentration in the grafted cucumbers fell below the K concentration in the nutrient solution within 5 hours after decapitation. The concentration of Mg scarcely changed with time after decapitation (Fig. 3).

Discussion

The various substances absorbed by the roots are generally considered to be carried up with the transpirational stream. In a decapitated

plant, exudation is undoubtedly the result of root pressure; the liquid being supplied by the root system to the upper parts of the plants (2). In the present study, the rate of exudation from the detopped plants was higher for the first one hour in the grafted cucumbers than in the non-grafted ones, but the situation was reversed within a few hours after decapitation. Similar results were obtained in the previous experiment (5). These results indicate that the root pressure of figleaf gourd falls lower faster than that of cucumber. The root weight of grafted cucumbers was far less than that of non-grafted ones, when they were grown under relatively low temperatures (3, 5, 7). Nevertheless, the exudation rate for the first one hour was higher in the grafted cucumbers than in the non-grafted ones, which suggests that the ability of water uptake in the intact plants was greater in the former than in the latter. Furthermore, the concentrations of $\text{NO}_3\text{-N}$ and P in the exudate were higher in the grafted cucumbers than in the non-grafted ones. The superior growth of cucumbers onto figleaf gourd may depend on its superiority in water uptake, and $\text{NO}_3\text{-N}$ and P absorption under relatively low temperatures.

The exudation rate decreased gradually with time after decapitation; however, it increased again during the following days and showed a diurnal change. Such diurnal change has been obtained repeatedly (data not shown). In these experiments, however, environmental factors such as temperature and light were not controlled. As shown in Fig. 1, the time of the maximum in exudation rate did not always coincide with that in the nutrient solution temperature. The maximum exudation was found about 2 hours earlier than the maximum solution temperature. Therefore, the diurnal change did not seem to be related directly to the change in the nutrient solution temperature. The maximum rate of exudation usually occurred around noon and the minimum rate occurred around midnight (4, 6, 8, 9, 10). Such diurnal change in the exudation rate can be reversed by changing the light-dark cycle under which the plants were grown (4, 6). These fact

may be due to an autonomic nature of the plant roots, which absorb water in keeping with transpirational demand during the day. However, Vaadia (8) suggested that an autonomic diurnal change in root pressure and exudation of sunflower plants was caused by the change of salt entry into the xylem. In the present study, among minerals such as $\text{NO}_3\text{-N}$, P, K, Ca and Mg, only $\text{NO}_3\text{-N}$ in the non-grafted cucumbers showed a tendency to increase during the day when the exudation rate increased. However, this phenomenon was not detected in the grafted ones. Therefore, diurnal change in the exudation rate did not seem to be related to mineral absorption of the roots.

The concentration of P in the exudate increased rapidly in the first several hours after decapitation. However, it is not evident whether the P absorption of the roots was promoted by decapitation.

The concentrations of $\text{NO}_3\text{-N}$, K and Ca were far higher in the first one hour exudate than in the nutrient solution. The concentrations in the exudate, however, decreased near to those in the nutrient solution sooner or later with time after decapitation. In particular, the $\text{NO}_3\text{-N}$ and K concentrations in the grafted cucumbers decreased below the concentrations in the nutrient solution. These results suggest that the nutrient absorption in the grafted cucumbers, i.e. in the root of figleaf gourd, may depend more intensely on the upper parts of the plants. Possibly it might depend on sugars or growth regulators supplied from the top.

Masuda *et al.* (5) pointed out that it was necessary to collect the exudate within one hour at least after decapitation to determine the representative mineral concentration in xylem sap. This necessity might be emphasized also by the fact obtained here that the exudation rate decreased rapidly with time after decapitation and that the mineral concen-

trations in the exudate changed remarkably with sampling times. Therefore, it seems necessary to investigate the first one hour exudate from separate plants decapitated hourly throughout the day in order to evaluate the difference in the mineral absorption of the roots between grafted and non-grafted cucumbers.

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接ぎ木・自根キュウリの茎切除後にみられる木部液の
いっ泌率と無機成分濃度の経時的変動

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摘 要

フィジフオリア台の接ぎ木キュウリと自根キュウリの養水分吸収に関する知見を得るため、茎切除直後から1時間ごとに木部いっ泌液を採取し無機成分の分析を行った。

いっ泌率は接ぎ木・自根とも最初の採取時で最も高く、採取時間が経過するにつれて急激に低下した。しかし、いっ泌率には日変化があり、その最大は茎切除の時刻に関係なく午後1時から3時の間に、最小は午前7時から8時の間に認められた。接ぎ木キュウリにおける日変化の振幅は自根キュウリのそれより小さかった。

最初採取時のいっ泌率およびいっ泌液の $\text{NO}_3\text{-N}$ 、P、Ca および Mg 濃度は接ぎ木キュウリで高かったが、K 濃度は逆に自根キュウリで高かった。これら成分の

濃度は採取時間の経過とともに大きく変動した。 $\text{NO}_3\text{-N}$ 、K および Ca 濃度は接ぎ木・自根とも茎切除後数時間で急激に低下し、P 濃度は急激に上昇した。Mg 濃度の変化は小さかった。さらに時間が経過すると、接ぎ木キュウリの $\text{NO}_3\text{-N}$ と K 濃度は培養液の濃度以下となったが、自根キュウリの $\text{NO}_3\text{-N}$ と K 濃度は培養液の濃度以下とはならなかった。

以上の結果より、接ぎ木キュウリの養水分吸収はKを除いて自根キュウリのそれより優れるものと思われた。また、接ぎ木キュウリの根の $\text{NO}_3\text{-N}$ と K 吸収は、自根に比べて茎葉から送られる代謝産物により強く依存しているものと思われた。