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# EFFECT OF MECHANICAL IMPEDANCE ON pH AND EXUDATION OF MAIZE ROOTS GROWN IN NUTRIENT SOLUTION

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A b s t r a c t. The effect of increased mechanical impedance on pH and release of organic substances by roots of maize grown in nutrient solution was studied. pH of the nutrient solution and release of water soluble and insoluble exudates per unit of root weight increased as mechanical impedance increased. Root and top growth was reduced with increasing mechanical impedance.

K e y w o r d s: mechanical impedance, pH, root exudation

## INTRODUCTION

Mechanical impedance of plant growth media is an important parameter affecting root growth and function [3]. Excessive mechanical impedance can be caused by natural factors, e.g., soaking, hardsetting or by compaction resulting from vehicular traffic [3,6]. It is generally accepted that increased mechanical impedance reduced root length, rooting depth and affects spatial arrangement of roots [8,15]. Lateral branching was increased [2,9,12,14], or decreased [2,14] depending on growth conditions and crop type. In addition, mechanical restraint caused the root axes of barley to curve around the restraint, and the initiation of laterals occurred on the convex (tension) side, whereas root hairs were more numerous on the concave (compression) side [4].

These alterations may affect soil reaction of growing media as root tips of most plants are particularly effective in changing pH. Root induced pH changes are brought frequently about by differences in net excretion of $H^+$ due to imbalance in the ratio of uptake of cations to anions, and the form of N taken up has the most prominent influence. In most plant species apical root zones increase the rhizosphere acidification and the rate of iron and manganese reduction and their uptake [12]. With the nitrate-fed maize, however, rhizosphere pH increased and it was most distinct along the main axes when the rhizosphere pH of lateral roots was either not increased or even decreased [10].

This activity of roots grown in mechanically impeded conditions was studied only in few studies [1,12] Mozafar [12], although root exudation largely contribute in total dry matter production [5].

This study evaluates the effect of various levels of mechanical impedance induced by ballotini in nutrient solution on pH and release of organic substances by roots of maize.

## MATERIALS AND METHODS

Seeds of maize weighing 0.28-0.32 g were selected. Germinated seeds were placed in the system of hydroponic, non-sterile cultures [11]. The treatments were: a) nutrient solution only; b) nutrient solution with 10 mm diameter

ballotini (glass spheres) and c) nutrient solution with 4 mm diameter ballotini. Mechanical impedance in treatment with glass spheres of 4 mm was greater than that in treatment with 10 mm spheres [13]. The plants were grown in a phytotron (growth chamber) with 16 h daytime temperatures of 22 °C and illumination of 400 ME $m^{-2}s^{-1}$ and 8 h nighttime temperatures of 18 °C. Relative air humidity was 60-70 % during whole 18-day experiment period.

The composition of nutrient solution was following: $K_2SO_4$ $0.7 \cdot 10^{-3}$M, NaCl $0.1 \cdot 10^{-3}$M, $Ca(NO_3)$ $2 \cdot 10^{-3}$M, $MgSO_4$ $0.5 \cdot 10^{-3}$M, $KH_2PO_4$ $0.1 \cdot 10^{-3}$M, $H_3BO_3$ $1 \cdot 10^{-5}$M, $MnSO_4$ $5 \cdot 10^{-7}$M, $ZnSO_4$ $5 \cdot 10^{-7}$M, $CuSO_4$ $2 \cdot 10^{-7}$M, $(NH_4)_6 Mo_7O_{24}$ $1 \cdot 10^{-8}$M, FeEDTA $1 \cdot 10^{-4}$M.

Nutrient solution was changed every two days to avoid insufficient plant supply with nutrients. At the time of the change initial and final pH was measured. At the end of experiment and before collection of the water soluble exudates the roots were placed in Erlenmayer's flasks with distilled water for 24 h. After filtration the water solution with the exudates were evaporated in temperature of 40 °C to the volume of 5 ml. The exudates insoluble in water were collected from root surface using vacuum water pump. The exudates both soluble and insoluble in water were then centrifugated, freeze-dried and concentration of carbon and nitrogen were determined. Root length was estimated by intersection method [16]. Leaf area and dry matter of shoots and roots were also determined.

## RESULTS AND DISCUSSION

### Plant growth

Increased mechanical impedance induced by ballotini glass spheres had significant effects on shoot and root growth of maize (Table 1). The highest shoot growth occurred in control solution and significantly decreased in treatments with glass spheres. The differences between treatments with ballotini of various diameter were relatively small. Total root length and root dry weight decreased in treatments with glass spheres, especially in treatment with glass spheres of 4 mm diameter. Data on specific root length indicate that the thinnest roots were in nutrient solution without ballotini.

**Table 1.** Effect of mechanical constraint on maize

| Characteristics of plants | Nutrient solution | Ballotini 10 mm | Ballotini 4 mm | $LSD^*_{0.05}$ |
|---|---|---|---|---|
| Shoot dry matter (g/plant) | 1.29 | 0.86 | 0.71 | 0.37 |
| Root dry matter (g/plant) | 0.29 | 0.29 | 0.23 | n.s. |
| Root length (cm) | 1445.0 | 1304.0 | 1085.0 | n.s. |
| Specific root length (m/g) | 49.82 | 44.96 | 47.15 | n.s. |
| Shoot:root ratio (g/g) | 4.45 | 2.97 | 3.08 | n.s. |

*-According to Tukey's test.

Shoot-root ratios characterizing dry matter partitioning were significantly lower and similar in both treatments with ballotini compared to nutrient solution only.

### pH

pH of the nutrient solution in all treatments sharply increased within first few days of growth and then remained almost unchanged (Fig. 1). The highest values occurred in treatments with 4 mm glass spheres and the lowest in nutrient solution. In experiment with barley performed by Mozafar [12], pH tended, however, to be higher in solution without glass spheres but absolute values were similar to those in our experiment. This contrast response in pH can be due to different forms of Fe used, Fe-reducing in Mozafar's study and Fe-EDTA in this study.

### Root exudation

The data in Table 2 show that release of water soluble exudates per unit length of root growing between ballotini of 4 mm diameter was considerably higher than that in remaining two treatments. This higher root exudation resulted in that the total release of water soluble

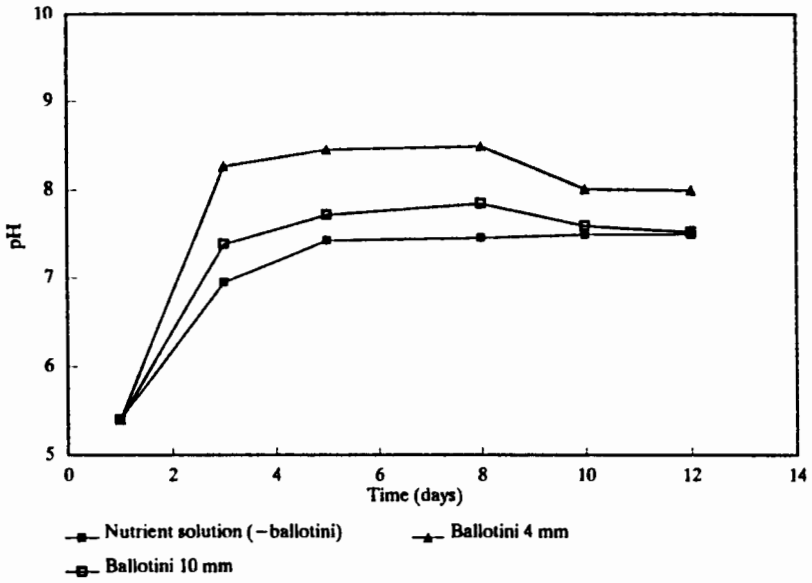


**Fig. 1.** pH of the nutrient solution as a function of days after planting.

**Table 2.** Characteristics of roots exudates

| Exudates | Nutrient solution | Ballotini 10 mm | Ballotini 4 mm | $LSD^{*}_{0.05}$ |
|---|---|---|---|---|
| Water soluble exudates (mg/plant) | 3.25 | 3.41 | 3.14 | n.s. |
| Water soluble exudates per 1g of roots (mg) | 11.21 | 11.75 | 13.65 | 1.45 |
| %C | 25.50 | 25.14 | 23.22 | n.s. |
| %N | 1.07 | 1.03 | 1.07 | n.s. |
| Water insoluble exudates (mg/plant) | 0.06 | 0.08 | 0.12 | 0.05 |
| Water insoluble exudates per 1g of roots (mg) | 0.21 | 0.26 | 0.52 | n.s. |

*-According to Tukey's test.

exudates was similar to that in two other treatments in which total root length was considerably higher. These data are in agreement with results of Barber and Gunn [1] and Mozafar [12] for barley and maize plants. They ascribed this increase to greater branching and increasing number of root tips. The increase in root exudation per unit of root was concomitant with decrease of carbon concentration in the exudates. Nitrogen concentration was not significantly different between the treatments. Release of exudations insoluble in water per unit of root weight increased in both treatments with ballotini and in the treatment with ballotini of 4 mm diameter glass spheres the exudation was up to nearly 2.5 higher compared to that in nutrient solution only. Total quantity of these exudates was relatively small and insufficient to determine concentration of carbon and nitrogen.

Hausling *et al.* [7] indicated that changes in rhizosphere pH can be related to root exudation. In this research increasing pH in treatment with impeded root was concomitant with greater root exudation. These aspects require further studies.

## CONCLUSION

Increase in mechanical impedance of nutrient solution induced by ballotini resulted in lower shoot and root growth of maize. Exudation of organic substances per unit root weight

and pH increased with increasing mechanical impedance while total exudation remained unchanged.

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## WPŁYW OPORU MECHANICZNEGO NA pH ROZTWORU ODŻYWCZEGO I WYDZIELANIE SUBSTANCJI ORGANICZNYCH PRZEZ KORZENIE KUKURYDZY

Badano wpływ zwiększonego oporu mechanicznego na pH roztworu odżywczego i wydzielanie substancji organicznych przez korzenie tej rośliny. pH oraz ilość wydzielin korzeniowych na jednostkę masy korzeni zwiększały się wraz ze wzrostem oporu mechanicznego. Wzrost korzeni i części nadziemnych kukurydzy był ograniczony w warunkach zwiększonego oporu mechanicznego.

S ł o w a k l u c z o w e: opór mechaniczny gleby, pH, wydzieliny korzeniowe, kukurydza.