Maize Growth and Ion Absorption in Richter's Solution at Different Flow Rates

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Received February 11, 1971

Abstract. By comparing maize plants cultivated in standing nutrient solution with those from solutions flowing at different flow rates it has been established that absorption of nitrogen, potassium and especially of phosphorus was increased owing to the flow. There was likewise a relative rise in the distribution of nutrients to the overground parts of the plants. The content expressed per unit dry matter was increased only in the case of phosphorus; with nitrogen and potassium it was slightly lower than in the standing solution. Increasing amounts of iron were required under the conditions of flowing nutrient solutions to prevent chlorosis of the plants. The production of dry matter, \( NAR \) and \( RGR \) was also increased because of the flow. The flow considerably changed the habitus of the primary roots of the maize plants. The roots were longer, thinner and on the whole they contained relatively less dry matter (\( RWR \)). The lengthening of the roots is explained as a response to stimulation by the solution flow — the rheotropism.

The nutrient solution used in the water culture may remain still, or may be stirred, or it may flow through the cultivation vessel round the roots (HAI and LAUDELOUT 1966, LAŠŤŮVKA and MINÁŘ 1967).

In the first case it is the diffusion which is the dominant process in ion absorption, in other cases the mass-flow (the stirring of the whole solution) becomes the most important factor (EATON and BERNARDINI 1964, SABET et al. 1964, HAI and LAUDELOUT 1966 etc.). HAI and LAUDELOUT (1966) found that the ion intake rate is equal to the product of the flow rate and the difference between the concentration of the solutions entering and leaving the cultivation vessel. This relation, however, holds true only within certain limits.

It is clear that the solution flowing round the roots removes the concentration gradient and is of some significance where the ion absorption rate is higher than the diffusion of the corresponding ion. The plant can remove the difference in ion consumption and supply, by the growth of roots and by thus increasing the absorption area. From the published findings, however (LEWIS and QUIRK 1965, 1967, BOULDIN 1961, OLSEN et al. 1962), it is clear that there are numerous conflicting opinions on this point.

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In this paper we have presented the results of experiments with maize in Richter's solution in which the solution flow rate round the roots was controlled. We were interested to find out whether and in what way certain physiological values vary at different rates of flow in this solution so well supplied with nutrients.

Material and Methods

Plant Material and Cultivation Technique

Maize (Zea mays L. cv. Kočovská raná IE) was used throughout our experiments. After five days of germination the maize seedlings (8 mg of dry root, 12 mg of sprout) were placed in containers and put into cultivation vessels.

These vessels, made of PVC and holding 13 l, were so arranged as to enable the solution to flow through a small tube of a given height and width. 48 plants were placed into each vessel, two of these together forming a series with the same rate of solution flow. In all, these variants of flow were used: 1. without flow, 2. a flow of 0.145 cm s⁻¹, 3. 0.238 cm s⁻¹, 4. 0.833 cm s⁻¹, 5. 2.000 cm s⁻¹. With the exception of the first variant 35 ml min⁻¹ of fresh nutrient solution flowed into each vessel. The nutrient solution was completely changed in the first variant twice a day to keep the total amount of solution used per plant and per day identical in all variants. The solution used was adequately aerated.

The experiments started on August 1, 1969. They were performed under the conditions of natural illumination in a greenhouse. The temperature of the air varied between 18 and 30 °C. The nutrient solution was not tempered.

Cultivation Solution and Sampling

In the experiments we used Richter's nutrient solution (1.0 R) (Laštůvka and Minák 1967) supplemented by 14 mg l⁻¹ of Fe, and a 1.5 times stronger solution (1.5 R) supplemented by 22.5 mg l⁻¹ of Fe. Iron was supplied partly in the form of Fe EDTA chelate. In the course of the experiments we took samples of 20 plants each for the estimation of dry matter and for the chemical analyses and of 4 plants each for the estimation of chlorophyll content.

Characters Evaluated

Chlorophylls a and b were estimated according to Šesták (1971, the calculation according to Vernon 1960), nitrogen, phosphorus and potassium according to the methods described by Minák and Laštůvka (1966), the relative growth rate (RGR) and the net assimilation rate (NAR) according to Laštůvka and Minák (1970a, b). The contents of the elements as well as the relative absorption rate (Iₐ) were calculated per g of dry matter of roots (Laštůvka and Minák 1970b).

The significance of the differences between the variant without flow and the others were estimated by G-test (Fryer 1957).

Results

The increasing flow of Richter's nutrient solution (1.0 R) influenced, sometimes very markedly, the set of the observed data. First of all the dry matter production was increased and more so in the overground parts of the plant than in the roots (Fig. 1). The maximum length of the root (Fig. 2) was increased by the higher flow in spite of the relatively lower root-weight ratio (RWR) of the whole plant. The values of RWR and RGR decreased in the course of vegetation, flow fastened the decrease of RWR more markedly than that of RGR (Fig. 3). The values of NAR in the distinct intervals tended to drop more in the standing culture (Fig. 4) with the exception of the last sampling in the course of vegetation. The content of chlorophylls a and b per unit dry matter of the overground part decreased nearly always

Abbreviations used: RGR -- relative growth rate; NAR -- net assimilation rate; RWR -- root-weight ratio; Iₐ -- mean rate of element absorption.