Early detection of sweet corn (*Zea mays var. rugosa*) nutrient deficiencies

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Abstract

Early recognition and detection of nutrient deficiency in plants is an important challenge from both crop safety and economic perspectives. An early indicator of a nutrient deficiency can be the examination of free-type, N-linked glycans in plants, and the detection of changes in their quality and quantity.

In the experiment described in this study, we aimed to investigate the nutrient supply of young corn plants using traditional biological method, as well as the N-glycan profile of the sap of these plants using matrix-assisted laser desorption, ionization mass spectrometry (MALDI-MS) method.

We wanted to prove that in the early phenophase of plants, a state of nutrient deficiency, which cannot yet be detected by traditional methods, induces a change in the quality and quantity of free N-glycans in plant sap.

In our experiment, corn (*Zea mays var. rugosa*) plants with different nutrient supply (3 treatments) were grown for 45 days from emergence. For laboratory tests plant samples were taken on the 45th day after the plants emerged.

The dry weight of the plant samples and their N-, P-, K-, Ca- and Mg content were measured.

The N-glycan profile of the plant juices was also examined using the matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS) method.

According to the results of our experiment, in this early phenophase of the plants (45 days), we did not experience statistically proven differences in the element content measured in the dry matter depending on the nutrients supply.

Analysis of the N-glycan profile of plant juices by matrix-assisted laser desorption/ionization mass spectrometry (MALDI-MS) showed significant differences between the amount of some N-glycans and the treatments. With this method, the plants of the T1, T2 and T3 treatments can be separated, nutrient deficiency can be detected even in such an early phenophase.

Key words: corn, nutrient deficiency, nutrient concentration

1 Introduction

In arable and horticultural crops, the quantity and quality of harvested products is largely determined by nutrient supply (Graeff et al., 2001; Balla et al., 2019). Biological methods (laboratory leaf and plant analysis) are used to assess the plant nutrient availability of the soil (Loch-Nosticzius, 2004).

The early detection of nutrient deficiencies in plants in a sustainable way (with as few laboratory measurements as possible) is an important challenge from both a crop safety and an economic point of view. One of the early indicators of stress could be the analysis of free-type N-linked glycans in plants, detecting their qualitative and quantitative occurrence and changes (Sasisekhara et al., 2006). The main role of N-glycans in plant cell life is in the coiling of proteins, in the recognition of those with defective spatial structures and in their degradation (Strasser, 2022). They are also important in plant cellulose biosynthesis and plant cell wall formation (Kang et al., 2008; Nagashima et al., 2018).

In present study, we aimed to investigate the nutrient supply of young corn plants by conventional biological method (concentration of nutrients of plants), furthermore the N-glycan profile of the sap of the mentioned plants by matrix-assisted laser desorption/ionization mass spectrometry (MALDI-MS).

2 Matherial and Methods

The experiment with the sweet corn (Zea mays var. rugosa) test plant was set up in the culture pot green house of the University of Debrecen, Institute of Agricultural Chemistry and Soil Science, with 3 treatments, 3 repetition, on sandy soil. The most important physical and chemical characteristics of the soil are presented in Table 1.

Each pot contained 3.5 kg air dry soil and four plants.

In our experiment, corn (*Zea mays var. rugosa*) plants with different nutrient supply (3 treatments) were grown for 45 days from emergence. Treatment 1 (T1) was used as a control, the plants did not receive any nutrient supplementation. Nutrients originally found in the soil were used for their development. The plants of the 2nd treatment (T2) received N-, P-, and K-nutrient supplementation in the form of inorganic fertilizers, taking into account the soil properties and the needs of the plant. In the 3rd treatment (T3), the corn plants were provided with the ideal amount of P and K, with a reduced addition of N fertilizer, thus inducing the N-deficient state. The treatment plan is shown in Table 2. Plant and soil samples were taken on the 45th day after the plants emerged.

The total nitrogen content of the corn samples was determined with the elemental analyzer operating on the combustion principle, using the "dry combustion" method (ELEMENTAR vario EL) (Nagy, 2000), the Ca, Mg, and K content was measured after destruction with a spectrometer (Varian AA10 Plus), while the P content was photometrically (Thamm et al., 1968).

For the statistical evaluation of the results (plant element content) were used the one-factor analysis of variance (Tukey test) of the SPSS program.

The N-glycan profile of the plant juices was investigated using the matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS) method (Dolatmoradi et al, 2024).

Table 1. Physical properties and chemical composition of sand used as the Control (Kincses et al., 2020)

K_A (Arany plasticity index)	<30
pH (in H_2O)	7.00
Humus content	0.6
Species soluble in AL (Egner et al. 1960)	mg/kg
AL-P_2O_5 (mg/kg)	88.1
AL-K_2O (mg/kg)	218.3
AL-Ca (mg/kg)	612
AL-Mg (mg/kg)	80.6

Table 2. Treatment plan of the experiment

Treatments	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Control (T1)	-	-	-
"Ideal" (T2)	225	117	198
Nitrogen deficient (T3)	21,3	117	198

3 Results and Discussion

According to the results of the experiment (Figure 1.), in such an early phenophase of corn, only the dry matter production of the non-fertilized plants (T1) is statistically lower than that of the fertilized ones. No significant difference was measured in the plant biomass of the nitrogen deficient (T3) and the ideal (T2) treatments.

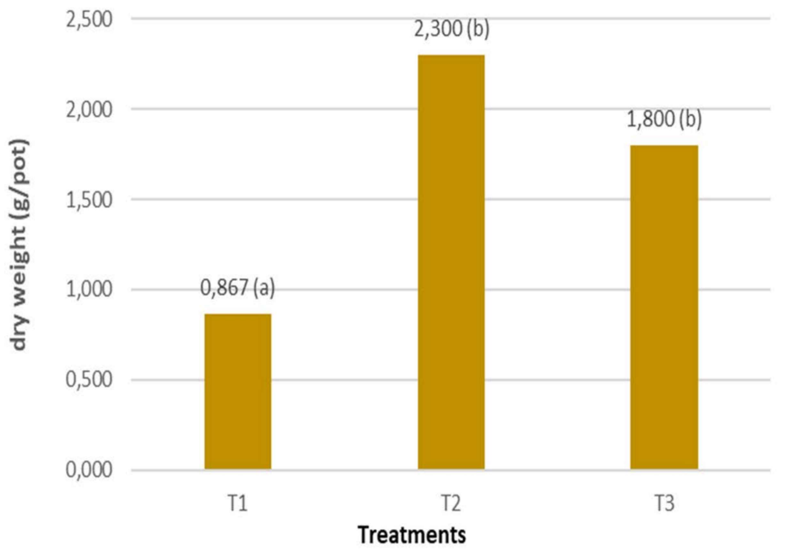

Figure 1: Mass (g/pot) of the young maize plant (dry matter)

Among the fertilized nutrients, the young corn plants receiving the ideal (T2) treatment contained nitrogen in a much higher concentration than the plants of the other two treatments (Figure 2). The difference was also statistically verifiable. The plants of the control (T1) and the treatments with a small dose of N-fertilizer supplementation (T3) cannot be distinguished based on this parameter. Due to the higher biomass production of plants treated with T3, their N-concentration showed a lower value (dilution effect).

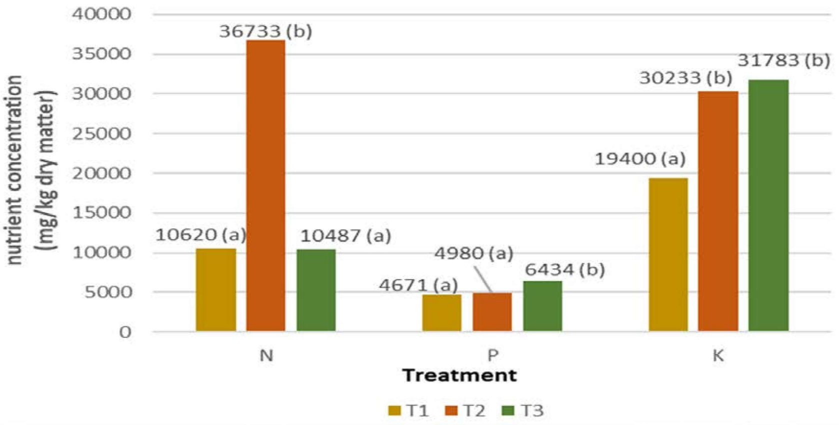

Figure 2: Concentration of fertilized nutrients of plants (N-, P-, K-concentration mg/kg dry matter)

The highest phosphorus concentration was measured in the N-deficient treatment (T3) plants, which was also statistically proven (Figure 2). In the dry matter of the plants of the treatments that received ideal nutrient supplementation (T2), the detected a P concentration was similar to the plants withouth phosphorus supplementation (T1).

The potassium concentration, as expected, was higher in the plants of the T2 and T3 treatments, and there was no significant difference between them. This nutrient was also measured in a low concentration in the plants of the T1 treatment (Figure 2).

Among the non-fertilized elements, the Ca concentration was not affected by the fertilizer treatments, while the Mg concentration was the lowest in the plants of the T3 treatment (Figure 3).

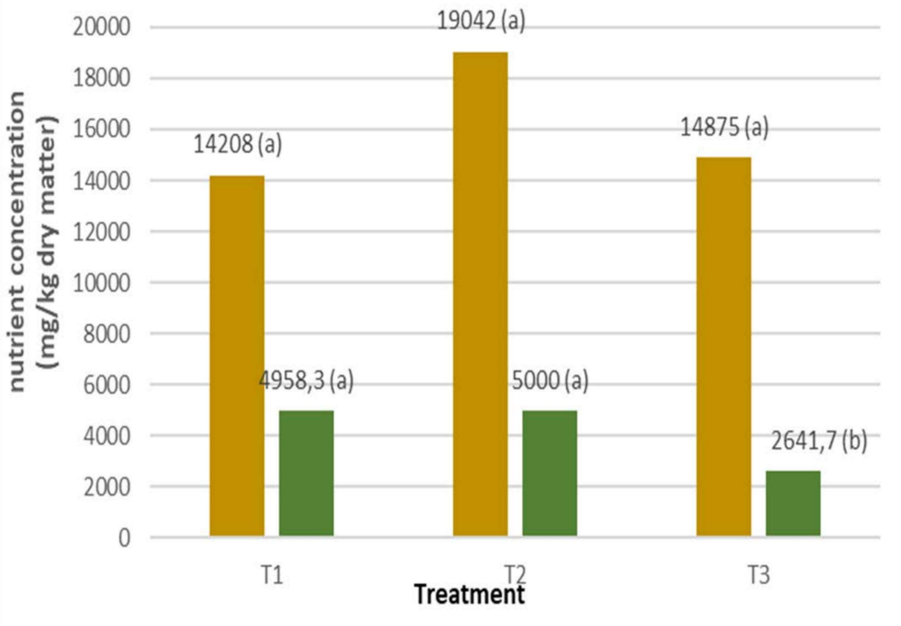

Figure 3: Concentration of non-fertilized nutrients of plants (Ca- and Mg-concentration mg/kg dry matter)

To find the spectral features that account for most of the differences between the spectra, multivariate statistical analysis was carried out by OPLS-DA. The rationale behind choosing OPLS-DA lies in the ability of this supervised model to identify variables that account for most of the differences between spectra from predefined sample groups. Score plots generated by OPLS-DA for the pairwise treatment comparisons with demonstrated clear distinctions between samples (Figure 4).

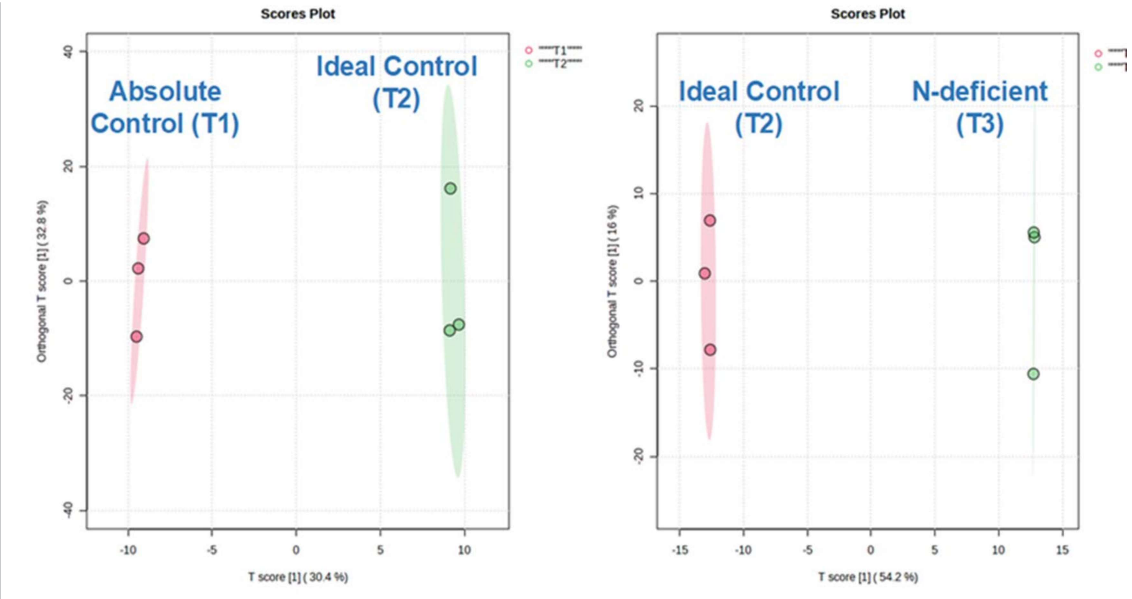

Figure 4: Scole plots for OPLS-DA of MALDI-MS spectra

4 Conclusions

Biological and chemical methods are used to assess the availability of plant nutrients in the soil and the nutrient supply. In our experiment, it was not possible to separate the plants of the T1 and T3 treatments based on the N concentrations measured in the dry matter. The P-concentrations showed no difference in the plants of the T1 and T2 treatments. The K-concentration of the plants of treatment T2 and T3 was almost the same. We detected a similar result in the case of non-fertilized nutrients (Ca and Mg).

According to the results of our experiment, in this early phenophase of the plants (45 days), we did not experience statistically proven differences in the element content measured in the dry matter depending on the nutrients supply .

Analysis of the N-glycan profile of plant juices by matrix-assisted laser desorption/ionization mass spectrometry (MALDI-MS) showed significant differences between the amount of some N-glycans and the treatments. With this method, the plants of the T1, T2 and T3 treatments can be separated, nutrient deficiency can be detected even in such an early phenophase.

Acknowledgements

The setup of the experiment processed in the publication and the chemical analysis of the experimental samples were realized within the framework of the PNYR:11048-2021-1.2.4-TÉT grant. Thanks for the opportunit.

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