USE OF TOMATO PLANTS AS BIOSENSORS IN GREENHOUSE FERTIRIGATION SYSTEMS

UTILIZAREA PLANTELOR DE TOMATE CA BIOSENZORI IN SISTEMELE DE FERTIRIGARE DIN SERĂ

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Abstract*. Numerous studies conducted in the fundamental fields of nutrition and irrigation are based on the phyto-chemical relationship between plants and the environment, a relationship that is reflected in technologies and, subsequently, in the quality and quantity of production. Research highlights the relationship between the value gradient of an electric current measured in the stem of tomato plants and the degree of water supply and nutrient solutions Eleven experimental variants had the role of highlighting the potential for variation of the electric current in the Brillante F1 tomato cultivar. The best results of the electric current, also reflected in the tomato production, were obtained at the level of V 8 variants (mix of potassium sulphate calcium nitrate potassium chloride) and V 9 (mix of applied solutions) at the time of application of the solutions nutrients and irrigation, to prevent the occurrence of abiotic stress.*
Keywords: tomato, biosensor, electric current, fertigation

Rezumat*. Numeroase studii realizate în domeniile fundamentale ale nutriției şi irigării se bazează pe relația fito-chimică dintre plante şi mediu, relație care se reflectă în tehnologiile de cultivare şi, ulterior, în calitatea şi cantitatea producției. Cercetările scot în evidență relația dintre gradientul valoric al unui curent electric măsurat în tulpina plantelor de tomate şi gradul de aprovizionare cu apă şi soluții nutritive. Unsprezece variante experimentale au avut rolul de a pune în lumină potențialul de variație al curentului electric la cultivarul de tomate Brillante F1. Cele mai bune rezultate ale curentului electric, reflectate şi în producția de tomate, au fost obținute la nivelul variantelor V8 (amestec de sulfat de potasiu + azotat de calciu + clorură de potasiu) şi V9 (amestec de soluții aplicate) la momentul aplicării soluțiilor nutritive şi a irigării, care să prevină apariția stresului abiotic.*
Cuvinte cheie: tomate, biosenzor, curent electric, fertirigare

INTRODUCTION

Currently, the introduction of automatic control techniques for the agricultural sector in production and post-harvest processes is experiencing a considerable increase. Obviously, the production stage in greenhouses is the most

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important and therefore a significant effort should be made to improve both the quantity and quality of fruit (Atheron and Rudich, 1994). Moreover, crop growth is mainly determined by climate variables and the amount of water and fertilizers applied through the irrigation system; thus, crop growth can be controlled by manipulating these variables (Rodríguez *et al.*, 2015).

The stimuli generated by an electrical signal, in response to changes in light conditions, water availability and nutrients, translate into a rapid response to the opening and closing of the stomata (Oyarce and Gurovich, 2010). In response to the dawn, there is a gradual increase in the electric potential, which reaches a maximum value until noon, to decrease in the evening, reaching lower values at night. In the case of fertigation, there is a significant variation of the electrical potential measured at the beginning and during the fertigation event (Achiței *et al.*, 2019).

MATERIALS AND MEHODS

The experiment was carried out in the experimental greenhouse of the "Ion Ionescu de la Brad" University of Agronomy and Veterinary Medicine Iasi, under controlled conditions.

Tomato seeds from the "Brilliant F1" cultivar were used in the experiment. This cultivar was selected because it is suitable for cultivation in protected areas and is known for its high yield in both conventional and hydroponic cultivation systems (Munteanu, 2003).

The study on the correlation of the technological requirements of tomatoes within the fertigation systems followed:

- Determining the variation of the electric current when using nutrient solutions with nitrogen;
- Determining the variation of the electric current when using nutrient solutions with phosphorus;
- Determining the variation of the electric current when using potassium nutrient solutions;
- Determining the variation of the electric current in case of using combined solutions;

For the study, 11 experimental variants were used, with 4 repetitions (tab. 1).

The water and mineral nutrition was ensured by using the nutritional solutions applied in the open circuit, without recovering and recycling the excess nutrient solution (Hartz *et al.*, 2005, Colpan *et al.*, 2013). For each plant was applied an amount of 30 ml/ solution/day and 0.5 - 1 L of water/day, depending on the phenological phase.

To prevent the application of water or nutrient solution at too short intervals, the crop substrate had a medium fineness to provide moderate retention capacity and to avoid root suffocation due to excess moisture, and used Kekkila peat as substrate (caliber 0-6 mm; pH 5.5-5.8; NPK 14-16-18 + microelements; with wetting agent; EC 2.5 mS·cm^{-1}).

Table 1

Experimental plots

Variants	Fertilizer
V1	fertilization with magnesium sulfate ($MgSO_4$)
V2	fertilization of potassium nitrate (KNO_3);
V3	fertilization with potassium sulphate (K_2SO_4)
V4	fertilization with calcium nitrate ($Ca(NO_3)_2$)
V5	fertilization with monopotassium phosphate (KH_2PO_4)
V6	fertilization with potassium chloride (KCl)
V7	fertilization with a mixture of magnesium sulfate + potassium nitrate + monopotassium phosphate
V8	fertilization with a mix of potassium sulphate+calcium nitrate+potassium chloride
V9	mixed fertilization (magnesium sulphate, potassium nitrate, potassium sulphate, calcium nitrate, monopotassium phosphate, potassium chloride)
V10	fertilization differentiated by days, for 6 days it will be fertilized separately with each product used in variants 1-6
V11	control variant

The concentration of the solution was not determined directly, but indirectly, by measuring its electrical conductivity (Weissert and Kehr, 2017). The water and nutrients supply of the plant were measured using two electrodes, inserted into the stem of tomato plants, at a distance of 25 cm from the ground and 60 cm between the electrodes (Baker and Bavel, 1987), connected to a pico-ammeter, Keysight B2981A, which can make measurements in the range of 0.01fA - 20mA (fig. 1).

Fig. 1 Picoammeter/Keysight B2981AFemto

Seed germination was performed in a growth chamber, under controlled environmental conditions (22°C, 75% relative humidity, 10 h - light, 10,000 Lux). When the first two leaves appeared, the tomato seedlings were transferred to 400 cm^3 plastic pots, using Kekkila peat (0-6 mm caliber) as substrate. At the age of 21 days, the plants were moved to the experimental greenhouse of the university, and at 42 days they were transplanted into 12 l plastic pots, using the same substrate, but with a caliber of 0-25 mm.

The care work of the tomato crop was carried out in accordance with the literature (Stoleru, 2013, Voican and Lăcătuş, 1998).

RESULTS AND DISCUSSIONS

As tomatoes have specific consumption, and both the deficiency and the excess of macro and microelements is quite harmful for metabolism, but especially for fruit quality, there is a need to dose fertilizers applied to crops. The functional principle of the system is based on the ability of a system to collect, interpret and control a circuit for the application of nutrient solutions and water (Suckhov *et al.*, 2018).

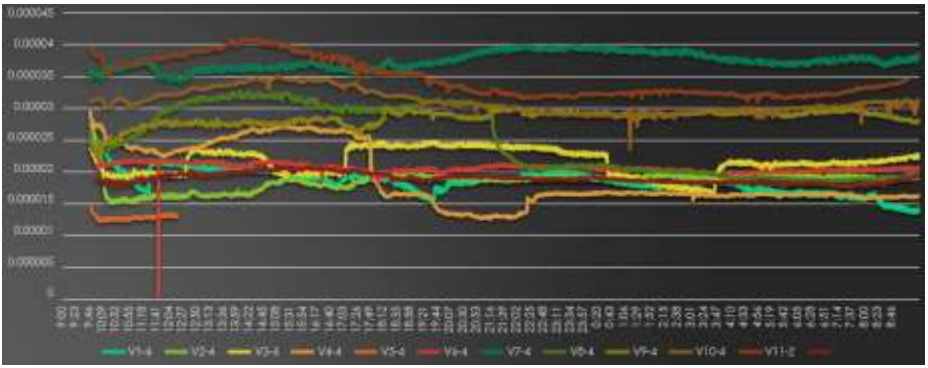

Fig. 2 Variations of electric current during 24 hours

The electrical signals recorded in a time interval of 24 hours, shows very large oscillations (Galle *et al.*, 2015), both within a single variant and between the 11 experimental variants (fig. 2).

Thus, at an interval of 24 hours, with readings at 60 seconds, the electrical signal recorded at variant V8 (fertilization with combined potassium sulfate + calcium nitrate + potassium chloride), the values of the electric current increase from 2.27x 10^{-5} A at 3.22x 10^{-5} A when applying the nutrient solution, maintaining relatively constant values until noon, following a downward trend to 2.91x10^{-5} A, then rising to values of 3 .06 x 10^{-5} A at 5 pm, when applying the watering norm. Values dropped to 2.03 x 10^{-5} A around 9 p.m (fig. 3).

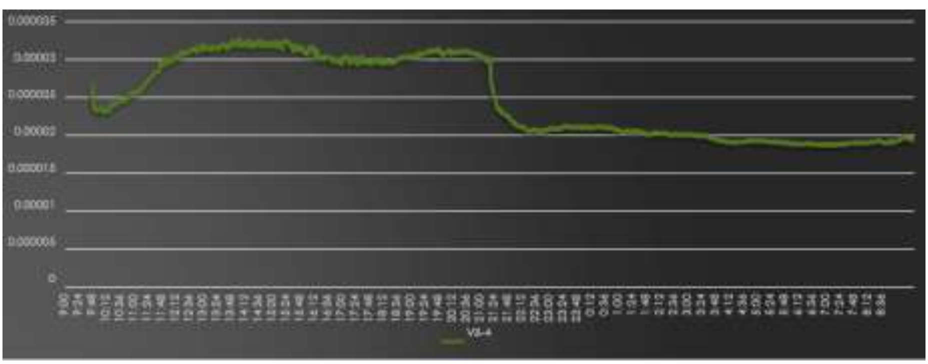

Fig. 3 Variation of electric current for V8

The electrical signal recorded in variant V9 (mixed fertilization - magnesium sulfate, potassium nitrate, potassium sulfate, calcium nitrate, monopotassium phosphate, potassium chloride), increases from $3x10^{-5}$ to $3,5x10^{-5}$A when applying the nutrient solution, maintaining relatively constant values until noon, reaching values of $2.9x10^{-5}$A in the evening, with small oscillations, until the morning of the next day, where it experienced increases up to $3.2x10^{-5}$A around 7:00 (fig. 4).

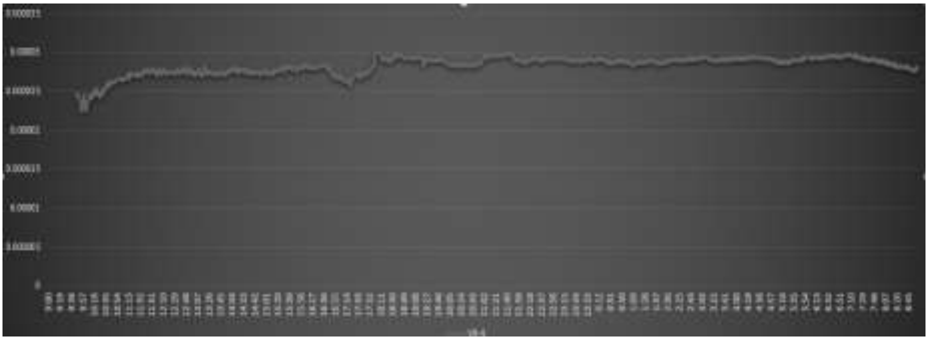

Fig. 4 Variation of electric current for V9

In variant V10 (differentiated fertilization per day, in which for 6 days it will be fertilized separately with each product used in variants 1-6), the values of the electric current started from $2.97x10^{-5}$ A, rising to $3.13x10^{-5}$ A at the time of application of the nutrient solution, and had an upward trend until noon, reaching values of $3.48x10^{-5}$ A, decreasing to $2.88x10^{-5}$ A towards dusk, values that remained approximately constant, and will increase to $3.05x10^{-5}$ A the next morning (fig. 5).

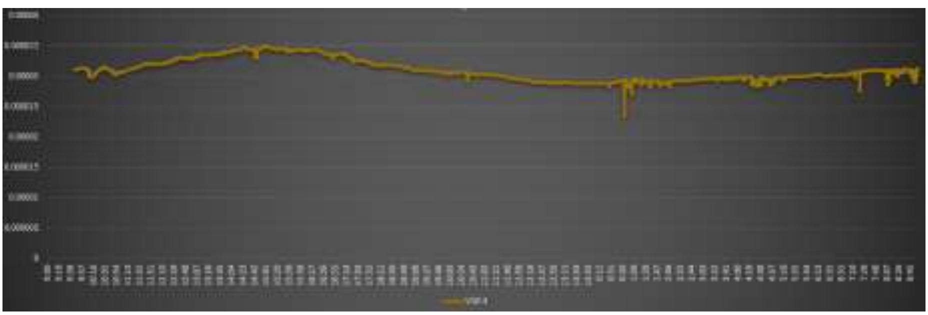

Fig. 5 Variation of electric current for V10

CONCLUSIONS

The values of the measured electric current vary depending on the type of nutrient solution applied, as it generally depends on the ion flow in the plant xylem specific to each type of fertilizer and phenophases.

A general analysis of the electric current values shows an increase in the intensity measured between the two electrodes when applying the nutrient solutions, values that remain relatively constant during the day, with a slight downward trend at noon and during the night, noting that the values recorded increase at the end of the day. Thus, it can be stated that the shape of the signal varies during the day depending on the period in which photosynthesis takes place, which means that it depends on the physiological processes of the plant and can be correlated with light.

Following the research, it turned out that the value of electricity generated by the plant is directly proportional to its metabolic mechanisms, respectively the values of electricity are higher when the flux of ions in the xylem of the plant is higher. In the biosensor system, the values of the electric current represent input data, on the basis of which a control system can generate a set of output data, which should control a fertigation system, as well as the parameters of the environment.

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