Study of the Passive Electrical Properties of Tomato Tissues after Infection and Treatment by Fungicide

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Abstract

Objective: To propose a method of electric detection of a biotic stress before the visible apparition of the symptoms on the plant leaflets. Methods/Statistical Analysis: By using Cole’s model of cell, we study the behavior of extra-cellular space resistance according to time of four groups of tomato leaflets and make comparison of those different behaviors. Findings: It appears from our analysis that the maxima of resistances leaflets which are infected by mildew and not treated increases gradually and tends to infinity. The infected plants (sick) and treated with the ridomil MC have a relatively low electric resistance level compared to that obtained in the infected and untreated plants. Whether the plants are infected, infected and treated, or healthy and treated; the maxima of resistances were higher than those in pilot plants (untreated and uninfected). The data shows that the disease destroys continuously the physiological state of the plant until death, which corresponds to the higher values of the extra-cellular space resistance peak; the fighting of fungicide against the disease within the plant organism has an impact on the physiological state of the plant which is revealed by the decrease of the extra-cellular space resistance peak. Application/Improvements: The objective being to contribute in obtaining a bank of numerical resistance values allowing improving the symptomatic methods of detection of the sick plants by the seeing and by the chemical analyses.

Keywords: Electrical Resistance, Fungicide, Mildew, Physiological State, Ridomil M.C. Cole’s Model of Cell, Tomato

1. Introduction

Generally, one can identify the sick plants i.e. plants which had undergone a biotic or abiotic stress starting from the appearance of the symptoms on the plants; however the appearance of the symptoms supposes that the plant already underwent a certain number of damages inside their tissues; which could have an influence on the quality and quantity of resulting product produced from these plants. Tomato, which is the most consumed vegetable in the world after potato contains a great quantity of rock salt, vitamin and the lycopene, which enables the human organism to resist cancer and the cardiovascular diseases. However, the tomato cultivated in Cameroun on a 76.000 ton scale per year; very sensitive, is often subjected to biotic or abiotic stresses, or both. Knowing that the electric reaction of the cell to an external stress will induce later on, a biochemical, physiological and or biophysics reactions in transitional period and that the passive electric characteristics reflect the degree of viability of a life cells and the organism as a whole. We will go as far as possible, considering a fungic stress, to study the behavior of extra-cellular space resistance of fabrics of tomato leaflets, when there are first of all treated by a fungicide; then when they are not treated; and at the end to make a comparative study with the results obtained of the healthy plants. The objective being to contribute in obtaining a bank of numerical resistance values allowing to improve the symptomatic methods of detection of the sick plants by the seeing and by the chemical analyses, to

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propose a method of electric detection of a biotic stress before the visible apparition of the symptoms; what will make it possible to the farmer to act quickly and effectively. The rest of the paper is therefore presented as follows: In section 2, we have presented the materials, explained the methods and the model that we used to obtain the results that are presented and discussed in section 3. Section 4 is devoting to some concluded remarks of the paper.

2. Materials and Methods

2.1 Preparation and Installation of the Seedbed

The black soil recovered in the surroundings of the campus of the University of Yaounde I was sterilized with the flame during 12 hours with an aim to eliminate all the pathogenic agents. This black soil was transported and put in two vats which were used as seedbed. The road repair of the seedlings in the bag was carried out 30 days after the sowing of tomato seeds in the seedbed. The growth of the tomato plants was maintained by regular watering. Measurements were taken on the tomato leaflets 75 days after sowing.

2.2 Obtaining the Fungic Inoculum and Infection of the Tomato Plants

In a peasant field at Obala, the tomato sheets carrying the typical symptoms of the mildew were taken and carefully transported to the laboratory of Phytopathology and Microbiology of the department of vegetable Biology. The infected parts of the sheets were cleaned with sterilized water, then cut out and incubated in a “wet chamber” in the boxes of Petri Figure 1 and Figure 2. The boxes were incubated for 7 days in darkness at ambient temperature (25±2°C). After formation of a cluster of mycelium, microscopic observations were made, followed by successive road repairs on PDA medium (Potato Dextrose Agar) for finally constituting a pure culture of *Phytophthora infestans*, which was to be used as inoculum for the artificial infection of the plants. To infect the plants, scarifications were realized on the level of the principal vein of the selected sheets. At the scarified place, the fungal inoculum was deposited using a needle then covered with cotton dampened with distilled water to maintain the necessary humidity to the development of the mushroom (Figure 3). The infection is successful if necroses increase on the limb of the sheet starting from the point of infection.
2.3 Treatment of the Tomato Plants with Ridomil MC
Fungicide “ridomil MC” is presented in the form of yellowish powder. The plants were treated by pulverization using an aqueous solution of ridomil MC in the proportions of water 3g/l. All the air parts of the plant were treated.

2.4 Experimental Device
To carry out measurements of extra-cellular space resistance with respect to the various stimuli (disease, plant health treatment), the plants were gathered in 4 batches making 4 experimental treatments as follows:
- the first group consists of leaflets that are infected and untreated
- the second group consists of leaflets that are infected and treated
- the third group consists of leaflets that are not infected and treated
- the fourth group consists of leaflets not infected and untreated (Pilot plants).

2.5 Model and Electrical Measures
The Cole model, which is the simplest electrical model for a biological body, is shown in Figure 4. The Cole model simplified biological tissue into a two-branch parallel circuit. R represents the extracellular space resistance, R’ represents the intracellular space resistance, and C represents the cell membrane capacitance. The current paths of different frequencies are illustrated in Figure 5. Tissue impedance at low frequencies is almost independent of cell membrane and internal resistivity, which is due to the cell membrane acting as a capacitor. The cell membrane is an open-circuit at very low frequencies, thus impedance is given by a purely resistive path: R. The cell membrane is a short-circuit at high frequencies (characteristic frequency), which is the maximum value of reactance.

\[ Z = \frac{R + R'R(R + R')}{1 + [C\omega(R + R')]^2} \]  

Where the real part and imaginary parts are given by

\[ Z_r = \frac{R + R'R(R + R')(C\omega)^2}{1 + [C\omega(R + R')]^2} \]  

\[ Z_i = \frac{CR^2\omega}{1 + [C\omega(R + R')]^2} \]  

The resistive and capacitive parts of the impedance respectively

\[ j = \sqrt{-1}, \omega = 2\pi f \]  

At zero frequency, i.e. \( \omega = 0 \);
\[ Z = R; \]  

While at infinite frequency, i.e. \( \omega = \infty \);
\[ Z = \frac{RR'}{R + R'} \]  

Having the intracellular space resistance

\[ R' = \frac{RZ}{R + Z} \]  

The measurement of the extracellular space resistance R of the leaflets is carried out according to equation (5) and by using a digital multimeter, initially before the
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3. Results and Discussion

3.1 Results

3.1.1 Development of the Tomato Plants
The results obtained from the parameters of the growth of the plants in seedbed and after road repair in the sachets showed that all the conditions were favorable to the development of the plants. All the seeds germinated after 4 days as of their ground setting. The vigorous plants were selected for the following tests, and their road repair out of sachets took place 30 days after the sowing of seeds. After the successful infections and the fungicide treatment by Ridomil MC according to the adopted experimental device, measurements of internal resistances were made to consider the physiological state of the plants.

3.1.2 Mildew Influence on the Physiological State of Tomato Tissues
Measurements of internal resistance of tomato tissues infected by *P. infestans*, agent responsible of the mildew, showed that the disease while developing in the vegetable organism (tomato) influences the state of the plant's tissues which results in to high resistance of tissues (Figure 6). Although resistance presents an alternative character, the maximum one (6.2 MΩ) was recorded at 26h compared to the sheets of the pilot plants where maximum resistance was 3.3 MΩ (Figure 9 and Figure 10).

3.1.3 Mildew Influence and Fungicidal Treatment on the Physiological State of Tomato Tissues
The infected plants (sick) treated with the ridomil MC had a relatively low electric resistance level compared to that obtained from the infected and untreated plants. The maximum resistance of the infected and treated one, 26 hours after application of fungicide was 5.7 MΩ (Figure 7 and Figure 6).

3.1.4 Action of Ridomil MC on Tissues of the Healthy Plants (Non-Infected)
After the first 14 hours following the application of the ridomil MC on the non-infected plants, the internal resistance of the plant is relatively low (1.02 to 2.3 MΩ). But from 14 to 26h after treatment, resistance increases by alternating peaks, to reach the maximum one of 4.6 MΩ at the 26th hours (Figure 8).

3.1.5 Physiological State of the Pilot Plants
The pilot plants are those which were neither infected, nor treated with the ridomil MC (Figure 9). Measurements have been taken under the natural conditions (in open air). The internal resistance level of these plants during the period of observation presented variations; but the
maximum resistance of the healthy plants was 3.3MΩ which is lowest compared to the cases previously studied. Whether the plants were infected, infected and treated plants, or healthy and treated; the maxima of resistances were higher than those in pilot plants (untreated and uninfected) (Figure 10).

Figure 8. Treated uninfected leaflet. After the first 14 hours following the application of the ridomil MC on the uninfected plants, the internal resistance of the plant is relatively low (1.02 to 2.3MΩ). But from 14 to 26h after treatment, resistance increases by alternating peaks, to reach the maximum one of 4.6MΩ at the 26th hours.

Figure 9. Non infected and untreated (Pilot plants). The maximum resistance of the healthy plants is 3.3MΩ.

3.2 Discussion

The majority of the methods used in vegetable physiology do not allow undertaking a continuous and simultaneous study of certain aspects of the vitality of the whole plant and its various organs. Nowadays, by using biophysics methods, it is possible to undertake a study on a précised aspect of the biology of a plant. The parameters such as internal electrical resistance, the impedance, the coefficient of polarization, determining the passage of the electrical current through a living tissue belong to the group of the passive electrical characteristics, which depend only on the physiological state of fabric, without any time to modify it. The objective of our study was to determine the physiological state of the tomato plants after the passage in the sheets of a D.C. current and under the effect of the stimuli such as the disease (mildew) and fungicide (ridomil MC). The artificial infection of the plants by *P. infestans*, agent responsible for the mildew of tomato showed that, two hours after the infection; the cells of the plant were subjected under pressure of the parasite. The propagation of the mildew on the tomato plant starting from the point of infection, can be explained by the systemic character of *P. infestans*, which has the capacity to be propagated through the plant by the flow of the matter moving in the phloem and in the extracellular matrix as Mutok Bakoume had shown in his similar tests on the cacao-tree (*Theobroma cacao*). The internal resistance of the infected plants (sick) increases and tends towards the infinite one. This could be explain by the fact that while the disease settling gradually in all the plants, the cells lose their vitality and the electrical current circulates with difficulty, which induces an increase of the extracellular resistance until the infinite one. These results corroborate those of obtained on the bioelectric activity of the sunflower following the infection of the diseases. In the healthy plants (not infected) treated with the Ridomil MC, systemic fungicide, the values of resistances to all the periods of observation starting from the 19th hour, were higher than those recorded in the sheets of the pilot plants (not infected and untreated). This shows that the physiological state of the plants treated with the Ridomil worsens while this chemical stimulus is present in the vegetable organism. In addition, the variation of the values of resistances as of the application of fungicide until the 26th hour shows an oscillatory character, corresponding to an excitation of the cells by the stimulus and a counterpart to the excitation by the cell whose physiological state is disturbed; what confirms the results obtained during the similar tests on potato. The action of fungicide being momentary is not dangerous for the plant. The oscillatory character of resistances was also noticed at the plants infected and treated with Ridomil MC. when it is known that the cellular wall allows water to pass freely, and that it has a certain selectivity with regard to the aqueous solutions, therefore ions; one can understand the oscillatory charac-

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ter of the extracellular resistance in the sense that, when the ions likely to cross the wall do it, this is translated at the electric level by a reduction in electric resistance; and when the nonselective ions are presented, the passage of these ones is stopped by the intermediary of the enzymes present in the wall; and that is translated at the electric level by an increase in the electric resistance of the extracellular medium. Moreover alternation of the peak, i.e. the passage of a high peak towards a low peak and vice versa, simply reveals that at the time the two moments of measurements, one passes from one physiological activity dominated by the formation of the non conducting organic matter i.e. insulating, to a physiological activity dominated by the production of the charge carriers such as ions and the electrons and vice versa; which is translated by an alternation of peaks of extracellular resistance.

Figure 10. Comparison of the four groups, whether the plants are infected, infected and treated, or healthy and treated; the maxima of resistances were higher than those in pilot plants (untreated and uninfected). The infected plants (sick) treated with the Ridomil MC have a relatively low electric resistance level compared to that obtained in the infected and untreated plants.

4. Conclusion

The purpose of this work is to analyse the behavior of the resistance of the tomato sheets infected by the mildew and untreated with the Ridomil MC, of the infected and treated sheets; treated sheets but not infected and the pilot plants with an aim of using the biophysical methods to diagnose the physiological state of the plants subjected to the disease and the fungicidal treatment. From the results obtained, one can say that an abrupt and persistent increase of the maxima of electric resistances would be synonymous to a deterioration or disturbance of the physiological state of the plant due to the biotic stress (disease); and that it is quickly necessary to intervene before the necrosis of tissues. Electric resistances obtained following the application of fungicide showed an oscillatory character of the state of fabrics and a momentary activity of the ridomil MC, and consequently, this fungicide does not have a negative impact on fabrics of tomato.

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