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CHANGES IN WATER RELATIONS, LEAF GAS EXCHANGE AND ELEMENTAL COMPOSITION OF PEACH LEAVES INFECTED WITH *TAPHRINA DEFORMANS* (BERK.) TUL

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Abstract

An investigation of water relations, leaf gas-exchange and elemental composition of healthy (control) and naturally infected with *Taphrina deformans* peach leaves was carried out. It was established that the water content and water potential were significantly higher in the infected leaves, while the relative water content and transpiration rate were not changed. The dark period respiration rate of infected leaves increased dramatically but the gross photosynthesis rate was strongly inhibited. The phosphorus and potassium content of infected leaves was higher than in the healthy leaves, but the content of other analysed elements diminished at different extent. The current work presents the results of the study related to the changes in water status, CO_2 exchange rate and elemental composition of *T. deformans*-infected peach leaves.

Keywords: peach (*Prunus persica*), *Taphrina deformans*, peach leaf curl, water relations, leaf gas exchange, mineral nutrients

INTRODUCTION

Peach leaf curl caused by *Taphrina deformans* (Berk.) Tul. is a widespread and economically important disease that affects orchards throughout the temperate regions of the world (Cissé et al., 2013). Its symptoms are related to distortion of leaves, their premature ageing and abscission. In some cases, in sensitive cultivars, the damages are found in fruits and shoots.

Along with the epidemiology data and control on the disease, a current aspect of the studies on the disease accesses the pathophysiological change in the host-pathogen system. It was found that the intensity of breathing increased by about 50% with the development of the pathological process. The photosynthesis was reduced and, in a number of cases, a negative rate of CO_2 exchange, moderate inhibition of photochemical processes and 30% to 50% decrease of the chlorophyll content were found in *T. deformans*-infected leaves compared to the control (Raggy, 1967, 1995). According to Nikolae & Mitrea (2009) the chlorophyll and water content in infected leaves by 53.62% and 1.87%, respectively. Montalbini & Buonaurio (1986) established that the chlorophyll content, reduced by 30% in the infected leaves, was due to the limited capacity for chlorophyll biosynthesis and not due to the increased chlorophyllase activity, as it is the case of some viruses.

To a large extent, the manifestations of the pathophysiological syndrome have already been described (Raggi, 1967, 1995, Sziraki et al., 1975, Montalbini & Buonaurio, 1986, Piperkova et al., 1998, Koleva-Valkova et al., 2017), however the causal relationships between the individual structural and functional disorders have not been fully explained.

The aim of the present study was to describe the physiological status of *T. deformans*-infected peach leaves focusing on

the changes in leaf gas exchange, plant water relations and content of important macronutrients.

MATERIALS AND METHODS

The study was carried out with healthy (control) and naturally infected with *T. deformans* leaves of Fayette peach cultivar. Due to the great diversity in the manifestations of the disease, the selected infected leaves were of the form "curly, chlorotic, without anthocyanin colouration", both without asci and after asci formation. The studies were carried out in laboratory conditions with leaves from annual shoots.

Leaf gas exchange was measured with a portable photosynthetic system LCA-4 (ADC, England) under controlled conditions. Dry weight (DW) was determined after drying the samples at 70°C for 48 hours. Water content (WC) was calculated as a percentage of fresh weight of the sample. Relative turgidity (RWC) was determined based on the fresh (A), dry (C) and turgid (B) weights of the samples using the formula: RWC = (A – C) / (B – C) × 100. Leaf water potential (Ψ) was determined with a pressure chamber EL 540 305 (ELE – International, England). The content of total nitrogen, phosphorus and potassium was established by standard methods and for Ca, Mg and Mn – after dry mineralization of the samples by atomic emission spectrophotometer (ISP-AES).

The results obtained were statistically processed and the significance of the differences was determined according to Student's *t*-test.

RESULTS AND DISCUSSION

The exterior appearance of healthy and *T. deformans*-infected leaves was significantly different. Infected leaves were strongly curled, thickened and their petiole area was up to 2-3 times larger than that of the healthy leaves. The changes were due to the pathogen-induced processes of hypertrophy and hyperplasia, increasing the size and number of the plant cells (Caporali, 1964). Indirectly, that was confirmed by the data on the specific leaf area (SLA), which decreased twice (Table 1).

Table 1. Parameters of water status and leaf gas exchange in peach leaves infected by *T. deformans*

Characteristics	Variants		
	Healthy leaves (Control)	Infected leaves (without asci)	Infected leaves (with asci)
SLA	18.20 ± 0.7	9.26 ± 0.5 (51)***	8.47 ± 0.4 (47)***
WC	69.05 ± 1.0	80.37 ± 0.7 (116)***	81.57 ± 1.1 (118)***
DW	30.95 ± 1.0	19.63 ± 0.7 (63)***	18.43 ± 1.1 (60)***
Ψ	- 10.6 ± 1.2	- 5.8 ± 0.8*	- 4.9 ± 0.7*
RWC	76.9 ± 5.3	78.9 ± 4.8 (103)	72.8 ± 3.9 (95)
E	3.85 ± 0.25	3.82 ± 0.17 (99)	3.71 ± 0.23 (96)
g_s	0.11 ± 0.02	0.12 ± 0.01 (109)	0.12 ± 0.02 (109)
R_D	4.91 ± 0.40	19.80 ± 1.50 (403)***	25.62 ± 2.35(522)***
A	22.87 ± 2.32	- 4.45 ± 0.25***	- 9.51 ± 0.84***
A'	27.78 ± 2.10	15.35 ± 1.07 (55)**	16.11 ± 0.97 (58)**
Total soluble sugars (glucose)	9.75	16.50 (169)	19.50 (200)

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

(Values in parentheses represent percentage of the variant relative to Control)

The results in Table 1 show that the absolute water content (WC) of the infected leaves was 16 to 18% higher than that of the healthy leaves and their water potential (Ψ) increased (values became less negative). The high WC was probably due to the larger absolute and relative volume of the vacuoles in the hypertrophied cells and the increased Ψ reflected the higher energy state of the free water in them.

Ψ – water potential (Bar); RWC – relative turgidity (%); DW – dry weight (%); WC – water content (%); SLA – specific leaf area (m^2 kg DW^{-1}); E – transpiration rate (mmol H_20 100 g DW^{-1} s^{-1}); g_s – stomatal conductance (mol H_20 m^{-2} s^{-1}); R_D – dark respiration rate (μmol CO_2 100 g DW^{-1} s^{-1}); A – CO_2 exchange rate (μmol CO_2 100 g DW^{-1} s^{-1}); A' – gross photosynthesis rate (μmol CO_2 100 g DW^{-1} s^{-1}).

No significant differences in the relative turgidity (RWC) were recorded, which indicated that water saturation of tissues did not change significantly. The transpiration rate (E) and stomatal conductance (g_s), which depend on the gradient between the concentration of water vapour in the intercellular spaces of the leaves and in the atmosphere and on resistance they experience while moving, were at the levels of the healthy leaves. The stability was probably a result of relatively the same turgidity of healthy and infected tissues as well as the unchanged resistance, since the hyphae of the pathogen were not located in the superficial palisade parenchyma and did not reduce stomatal width (Caporali, 1964).

The lower percentage of dry weight (by 37 to 40%), was, on the one hand, directly related to the increased WC of the infected leaves, and on the other hand, it was a consequence of the dark respiration rate (R_D), which has increased several times. The respiratory exchange ratio corresponded to the higher amount of soluble sugars in the infected leaves.

The results in Table 1 also show that CO_2 exchange rate (A) in *T. deformans*-infected leaves was a negative value. In the current case, it expressed the rate of net photosynthesis, since photorespiration was practically absent due to the increased concentrations of CO_2 (5). If we assume that with a negative carbon balance of the gas exchange, R_D was not significantly suppressed by light, the values of true (gross) photosynthesis (A') in the infected leaves reached 55-58% of that of the healthy ones. These values generally corresponded to the established moderate decrease in the photosynthetic pigments and to the relatively high functional activity of photosystem 2 (Piperkova & Vasilev, 2000).

The results in Table 2 show that of total nitrogen, calcium, magnesium and manganese in the infected leaves decreased and the content of phosphorus and potassium increased. No significant differences were observed between the variants with and without formation of pathogen asci. The increased content of potassium cations can be related to the high osmotic potential and WC of the infected tissues. The increased phosphorus content reflected the increased energy needs of the host-pathogen system and was the result of its increased absorption of the necessary mineral elements. A significantly lower content of total nitrogen (17 to 38%) indicated that the protein in the cytoplasm of the cells decreased, which is a prerequisite for disturbances in its structural and functional activity.

A calcium content was significantly reduced (54 to 69 %) and that was probably one of the reasons for the incomplete construction of the cell walls of the hypertrophied cells. The established lower values of Mg and Mn corresponded to the reduced photosynthetic pigments content (Piperkova et al., 1998) and reduced photosynthetic rate (A').

Table 2. Content of macro- and trace elements in peach leaves infected by *T. deformans*

Content of mineral elements	Variants		
	Healthy leaves (Control)	Infected leaves (without asci)	Infected leaves (with asci)
Total N (%)	3.62	2.99 (83)	2.24 (62)
P_2O_5 (%)	0.58	0.70 (121)	0.68 (117)
K_2O (%)	2.73	3.05 (112)	2.90 (106)
Ca (ppm)	15868	7266 (46)	4862 (31)
Mg (ppm)	4610	2362 (51)	2029 (44)
Mn (ppm)	44.74	24.77 (55)	33.68 (75)
Total soluble sugars (glucose)	9,75	16.50 (169)	19.50 (200)

Values in parentheses represent percentage of the variant relative to Control

CONCLUSION

The established changes in some physiological parameters of peach leaves, Fayette cultivar, infected with *T. deformans*, demonstrated that the pathogen has a strong impact on the physiological status of the infected plants. Water content and water potential were significantly higher in the infected leaves, while the relative water content and transpiration rate remained unchanged. The dark respiration rate of infected leaves increased dramatically but the gross photosynthesis rate was strongly inhibited and this was probably related to the lower percentage of dry matter of the infected leaves. Phosphorus and potassium contents were higher than in the healthy leaves but the contents of the other analysed elements were reduced to different degrees.

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