Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 16(4), 47-56
Received: 29.06.2025 Revised: 30.10.2025 Accepted: 27.11.2025

UDC 633.11:579.84

DOI: 10.31548/plant4.2025.47

Liliia Pavliuk*
PhD, Researcher
Research and Breeding Institute of Pomology "Holovousy"
50801, 129 Holovousy Str., Holovousy Village, Czech Republic
https://orcid.org/0000-0002-5357-9322

Michaela Marklová
Engineer, Researcher
Research and Breeding Institute of Pomology "Holovousy"
50801, 129 Holovousy Str., Holovousy Village, Czech Republic
https://orcid.org/0009-0001-0879-359X

Assessment of the physiological state of the P-HL-A rootstock under conditions of phytoplasma infection

Abstract. The relevance of the study was conditioned by the significant influence of phytoplasma infections on the productivity and physiological state of rootstocks of garden crops, which created risks for the survival and development of buds during grafting and their further growth. The purpose of the study was to evaluate the physiological suitability of the P-HL-A rootstock in conditions of potential or existing phytoplasma infection during grafting. To achieve this goal, methods of molecular diagnostics were used, namely polymerase chain reaction (PCR) in real time to determine the presence of a pathogen, analysis of leaf tissue turgescence to assess water deficiency, and spectrophotometric determination of photosynthetic pigments (chlorophylls and carotenoids). Changes in the water regime and functional state of the photosynthetic apparatus of P-HL-A rootstocks depending on the degree of infection were studied. It was found that phytoplasma damage causes water deficiency in the range of 31.6-37.5% and a decrease in relative turgescence to 62.4-68.4%, which indicated the development of moderate water stress. The content of photosynthetic pigments was analysed, which decreased by 11.9-33.3% depending on the type of pigment and the level of infectious load. It was generalised that the initial exposure to the pathogen was manifested by a decrease in cell turgor and photosynthetic activity, which can negatively affect kidney survival during inoculation. The practical significance of the study lies in the fact that the results obtained can be used by gardeners, agronomists, and researchers in nurseries and research stations to optimise agrotechnical measures, control phytoplasma infections, and increase the efficiency of reproduction of fruit crops

Keywords: water deficiency; photosynthesis; cell turgescence; chlorophyll; carotenoids

Suggested Citation:
Pavliuk, L., & Marklová, M. (2025). Assessment of the physiological state of the P-HL-A rootstock under conditions of phytoplasma infection. *Plant and Soil Science,* 16(4), 47-56. doi: 10.31548/plant4.2025.47.

*Corresponding author

INTRODUCTION

The relevance of the study is conditioned by the growing spread of phytoplasma infections in European fruit crops and the high risk of their transmission during vegetative reproduction. This creates the need to investigate the functional stability of rootstocks used in intensive gardening technologies. Studying the effect of phytoplasma damage on rootstocks is important because these infections are quite common, easily transmitted during vegetative reproduction, and can reduce the compatibility and productivity of fruit crops. The study allows assessing the risks of using infected material and ensuring the effectiveness of vaccination.

Nowadays, gardening is constantly influenced by numerous abiotic and biotic factors that significantly determine the productivity and quality of fruits. A number of researchers such as T. El-Mageed *et al*. (2021), A. Mekdad *et al*. (2021), A. Shaaban *et al*. (2022), showed that abiotic stresses, in particular drought, lower temperatures, and spring frosts, can lead to a significant decrease in garden yields. Simultaneously, biotic factors, including viral, bacterial, and phytoplasma infections, pose a serious threat to plant growth and development. One of these threats is infection of plants with phytoplasmas – phytopathogenic bacteria. According to the literature analysis by R. Wang *et al*. (2024), phytoplasmas used to be called MLOs, and now they belong to the genus '*Candidatus* Phytoplasma ' in the class Mollicutes. The main classification method is analysis of the 16S rRNA gene, with two strains considered different species if their similarity is less than 98.65%, and ANI (threshold 95-96%) is used for full-genome comparison. If this data is insufficient, MLSA is used. Phytoplasmas are further divided into 16sr groups and subgroups using RFLP analysis or the virtual iPhyClassifier tool. There are 48 known *Ca* species. Phytoplasma, grouped into 37 groups, for example, in the 16srxii group there are five species that belong to different subgroups.

In particular, G. Asudi *et al*. (2021) found that phytoplasmas cause morphological and physiological disorders such as leaf yellowing, dwarfism, and leaf blade reduction, accompanied by reduced photosynthetic activity and limited transpiration. In addition, these researchers proved that systemic exposure to phytoplasmas can reduce the chlorophyll content and plant resistance to abiotic stresses, and in severe cases – cause plant death. S. Ahmad *et al*. (2019) noted that this leads to limited nutrient transport in the plant. According to the current protocols, phytoplasmas are included in the diagnostic protocols of the European and Mediterranean plant protection organisation EPPO Global Database (2023), which are regulated by the relevant standards. In particular, these include: PM 7/62 (3) '*Candidatus* Phytoplasma mali', '*Ca*. P. pyri' and '*Ca*. P. prunorum' and PM 7/150 (1) '*Candidatus* Phytoplasma phoenicium'. According to the requirements of the EPPO Global Database, mandatory testing for the presence of phytoplasmas is provided for such stypes of fruit crops as pome, stone, and vine. According to A. Konup *et al*. (2019), the correlation of the main groups of infectious diseases was determined in viticulture. It was found that among the detected pathologies of the vine, about 10% are viral diseases, approximately 25% are bacterial cancer, while the dominant share, about 65%, is phytoplasma diseases. Phytoplasma is also common in orchards of the Czech Republic. L. Valentová *et al*. (2022) found that phytoplasma is common in 80% of the pear samples examined. In general, according to the EPPO Global Database, this disease is widespread throughout the European continent.

Special attention is drawn to the risk of spreading phytoplasmas through vegetative reproduction, in particular during vaccination, which creates a threat of infection of both rootstocks and inoculations, as noted by R. Wang *et al*. (2024). This makes it relevant to investigate the effect of phytoplasma damage on the functional state of rootstocks, which is important for ensuring the effectiveness of grafting and preserving the productivity of garden crops. In the context of potential or existing phytoplasma damage, it is advisable to assess the physiological suitability of the rootstock used for grafting. The choice of rootstock P-HL-A as an object of research is conditioned by the need to determine its ability to maintain functional indicators and stability during intensive agrotechnical grafting. The rootstock is characterised by a reduced growth force, which is approximately

60% relative to wild mazzard cherry seedlings. It is recommended for use in intensive plantings in conditions of irrigation, the use of supporting structures, and high soil fertility. It is characterised by a high level of compatibility with most varieties and is characterised by a good ability to vegetative reproduction by both green cuttings and cultivation methods *in vitro*. The scientific originality consists in a comprehensive analysis of the effect of phytoplasma infection on the functional state of the P-HL-A rootstock of Czech selection in practical growing. The results obtained allow assessing the risks associated with the use of contaminated materials and develop recommendations for the use of healthy rootstocks to ensure successful grafting and maintain high productivity of garden crops.

The purpose of this study was to evaluate the physiological suitability of the P-HL-A rootstock under conditions of potential or existing phytoplasma infection during intensive agrotechnical grafting.

LITERATURE REVIEW

Contemporary studies demonstrate a significant influence of both biotic and abiotic stress factors on fruit crops and emphasise the complex interaction of these factors in agroecological conditions and their impact on the physiological state of plants. One of these factors is phytoplasma diseases, which can manifest typical symptoms or remain asymptomatic depending on the concentration of the pathogen in the plant tissues, the type of plant and its growing conditions. Phytoplasma diseases are an important pathogenic factor for both perennial and annual plants. They are characterised by the ability to spread unevenly through host tissues, which makes it difficult to accurately assess the degree of damage and the dynamics of disease development. In particular, the study by V. Singh *et al*. (2018), demonstrates that in sesame plants, phytoplasma concentrations in the early stages of infection positively correlate with disease severity. In later stages, there is a decrease in the level of the pathogen. In addition, significant changes in phytoplasma concentrations were recorded between the upper and lower parts of plants, with the distribution pattern varying from the early to late stages of infection development. These data confirm the uneven distribution of phytoplasma in plant tissues, regardless of their age and life expectancy. Morphological changes that accompany phytoplasmic infections are also well documented in potato and tomato plants. Y. Arocha *et al*. (2007) noted that the disease begins with the development of additional lateral shoots that quickly lengthen and sprout through the top of the plant, giving it a branched appearance. In addition, there is a decrease in the size of the leaves, their twisting and yellowing. These symptoms reflect a violation of the hormonal balance of the plant, which leads to changes in normal growth and development and are typical of phytoplasma infections. The study by S. Ahmad *et al*. (2019) showed that phytoplasma infection in sesame seeds causes significant changes in plant metabolism and antioxidant protection, including increased activity of catalase, superoxide dismutase, and peroxidase enzymes, increased levels of phenols, proteins, proline, and glycynbetaine, and an increase in malone dialaldehyde and hydrogen peroxide while reducing soluble sugars.

There are also studies that note the negative impact of phytoplasma infection on the physiological state of the plant, in particular, on a decrease in photosynthetic activity. For example, A. Bertaccini *et al*. (2014) and V. Kuyan (2016) indicated that phytoplasma infection leads to a significant decrease in the content of chlorophyll and carotenoids in apple leaves, disrupting photosynthesis. In addition, there is a decrease in the level of soluble proteins, in particular ribulose-1.5-bisphosphate carboxylase, and a decrease in the activity of photosystem 2 and nitrate reductase. Infection also reduced the content of specific thylakoid membrane proteins involved in water photolysis. The most relevant one for this study was the paper by Y. Tan *et al*. (2015), who investigated the effects of phytoplasma infection on sweet cherrytrees. In the course of the study, characteristic morphological changes in the leaf blade and shoots were described, in particular, shortening of internodes, reducing the size of leaves, their yellowing, wrinkling, and twisting. In addition, a negative effect on plant physiological processes was recorded: infected leaves were characterised by a decrease in the chlorophyll content, a significant decrease in the evaporation rate, a decrease in stomatal opening (Gs), an increase in the concentration of CO_2 in the intercellular space (Ci), and a decrease in intracellular resistance (Ls). Phytoplasma infection also led to significant changes in the hormonal balance in the leaves: an increase in cytokinin (ZT) levels was noted, while a decrease in the concentrations of gibberellins (GA) and abscisic acid (ABA). Elevated ZT levels stimulate abnormal cell growth and the development of additional shoots, while reduced GA and ABA inhibit normal leaf and stem development and reduce the plant's stress tolerance. Thus, the effect of phytoplasma on leaf morphology and development is mainly conditioned by a violation of hormonal regulation, and not just mechanical tissue damage. The negative effect on plant physiological processes was confirmed by X. Bai *et al.* (2009). In particular, G. Asudi *et al.* (2021) showed that NGS phytoplasma infects napier grass, disrupting the morphoanatomic structure of phloem and the transport of photosynthetic products, leading to inhibition of growth, leaf chlorosis, and activation of defence mechanisms through the accumulation of reactive oxygen species.

Given the significant influence of phytoplasma infections on the morphology, physiological processes, and hormonal balance of plants, an important aspect of their study is understanding the mechanisms of spread of these pathogens in cultivated plants, because it is the transmission routes that determine the rate of infection and the effectiveness of disease control measures. According to R. Tedeschi & A. Alma (2006), the main vector of pathogen transmission is cicadas. Simultaneously, an effective plant protection system can reduce transmission of infection through vector insects. But the infection that occurs during agrotechnical procedures, such as vaccinations, is almost impossible to limit.

Since grafting is one of the key methods of propagation of planting material, it is also one of the main ways of spreading pathogens, in particular phytoplasmas. According to K. Caglayan *et al.* (2023), phytoplasma transmission during grafting was recorded in pears, jujuba, and grapes. Research by S.-H. Lee *et al.* (2012) showed that it takes about 28 days to detect phytoplasma in a plant after grafting. It was found that at the initial stages, phytoplasma particles are localised mainly in the root system, and after 82 days the infectious agent spreads to all organs of the plant.

Thus, numerous research results confirm that phytoplasma infections have a complex negative impact on the morphology, physiological state, and hormonal balance of plants, disrupting their normal growth, development, and resistance to stress factors. Given that grafting is one of the most common methods of propagation of planting material, but simultaneously one of the main ways of spreading phytoplasmas, it is particularly important to study their impact on the quality of the rootstock and its ability to ensure the water and physiological balance of the bud.

MATERIALS AND METHODS

Location and objects of research. The study was conducted in 2025 at the Research and Breeding Institute of Pomology "Holovousy" (Czech Republic), in the Department of the Fruit genetic resources. Rootstock for cherries and sweet cherries P-HL-A was used as the object of research. The presence of European Stone Fruit Yellows (ESFY) phytoplasma in plant material was preliminarily confirmed by polymerase chain reaction (PCR). According to the results of molecular diagnostics, all samples were classified into three conditional groups depending on the number of amplification cycles: PP (potentially positive), + (weakly positive), ++ (clearly positive). Plants in which the pathogen was not detected were used as a control group. Sampling was carried out in the third ten days of July, immediately before the start ofbudding, in order to assess the physiological state of the rootstocks before budding. Tissues were taken from four opposite sides of each plant at the same height, which ensured the representativeness of the samples. The experiment was performed in four repetitions, each of which included two plants.

Determination of plant water deficiency. To assess the water regime of the leaf tissue, turgescent properties were analysed using die-cuts. From the leaf blade, avoiding the main veins, 10 disk die-cuts were obtained using a drill with a diameter of 8 mm. The samples were weighed (raw mass before immersion), then placed in distilled water in Petri dishes for 2 hours. After incubation, the leaf discs were carefully drained with filter paper and re-weighed (raw weight after immersion). To control the complete water saturation, the die-cuts were again submerged in water for 30 minutes and re-weighed. The samples were then dried in a drying cabinet for 40 minutes at 120°C, after which the dry weight was determined.

Based on the obtained data, the following indicators were calculated:

- Initial water content (g): raw weight before immersion – dry weight.
- Amount of water in the state of turgescence (g): raw weight after immersion – dry weight.
- Water deficit (%): ((amount of water in the turgescence state – initial water content) / amount of water in the turgescence state) ×100.
- Relative turgescence (%): ((crude weight before immersion – dry weight) / (crude weight after immersion – dry weight)) ×100.
- Relative turgescence deficit (%): 100 – relative turgescence.

Determination of green pigments in the plant. The samples were ground using liquid nitrogen in the presence of a small amount of $MgCO_3$. 20 mg of the resulting material was taken from ependorf-type tubes, after which 1.5 ml of methanol was added. After short-term stirring, the tubes were centrifuged for 5 minutes at 16,000 g. The content of chlorophyll a, chlorophyll b, and carotenoids in the supernatant was determined by the Wellburn method using a Genesys 180 spectrophotometer (USA).

Statistical processing of results. Statistical processing of experimental data was performed using Minitab 19 software suite (Minitab LLC, 2019). Before performing a univariate analysis of variance (ANOVA), the data were checked for normality using the Kolmogorov-Smirnov criterion. Statistically significant differences between the mean values were determined using the Tukey test at a significance level of $p \leq 0.05$.

Ethical standards. The study was conducted in accordance with the ethical standards of the Convention on Biological Diversity (1992) and Convention on the Trade in Endangered Species of Wild Fauna and Flora (1976). Only plant material (P-HL-A rootstock) was used in the work, without the involvement of animal or human experiments.

RESULTS AND DISCUSSION

Lack of water limits plant productivity and yields in various ecosystems and agriculture. In addition to the ability to survive acute drought stress, which depends on the genotypic characteristics of the plant, the strength and duration of exposure, the speed and efficiency of recovery also play an important role in determining productivity. A study of the effect of phytoplasma infection on water deficiency in plants showed that all the samples under study were in a state of water stress. The standard value of water deficiency (WD) for physiologically healthy plants is 5-10%, while in the presented study, even control, uninfected samples showed WD at the level of 23.9%. The results show that even control, uninfected plants experienced severe water stress, since the level of their water deficiency significantly exceeded the physiological norm. Infected samples, depending on the degree of infectious load, had a significantly higher level of water deficiency – from 31.6 to 37.5%, which indicates a reduced adaptive ability of such plants to arid conditions. This indicates a direct effect of the pathogen on the water balance of plants.

In particular, the water deficit in PP samples (potentially positive) exceeded the control value by 7.7%, in + samples (weakly positive) – by 8.9%, and in ++ samples (clearly positive), respectively, by 13.7%. Although the analysis of variance did not reveal a statistically significant difference between individual infection groups, there is a clear tendency for water deficiency to increase with increasing infectious load. This indicates a negative effect of phytoplasma infection on the water balance of rootstocks, which may have adverse effects on bud survival during grafting (Table 1).

An important indicator of the water status of plants is relative turgescence (RT), which characterises the ability of cells to maintain turgor under stressful conditions. According to the generally accepted classification by M. Laxa *et al*. (2019), RT values in the range of 60-70% indicate moderate water scarcity. The results showed that control samples with a RT score of 76.1% were in a state of minor water stress. Simultaneously, plants infected with phytoplasma showed lower RT values – from 62.4 to 68.4%, depending on the degree of infection, which indicates the development of moderate or even severe water deficiency. This condition potentially disrupts the physiological and biochemical processes in the plant , in particular metabolism, water exchange, and transport of assimilants, and can have a negative impact on the overall functioning of the plant. Analysis of relative turgescence deficiency (RTD) indicators shows an increased need for water in infected plants to maintain a normal functional state.

Table 1. Physiological state of plants under conditions of varying degrees of phytoplasma infection (2025)

Indicator / Sample	Water deficit indicators, %			Indicators of pigments, mg/g			
	WD[1]	RT[2]	RTD[3]	*a*	*b*	*a+b*	*karot.*
P-HL-A (k)	23.9±5.5 a	76.1±1.0 a	23.9±1.0 a	0.48±0.15 a	0.11±0.03 a	0.59±0.18 a	0.21±0.06 a
P-HL-A (pp)	31.6±6.2 b	68.4±5.6 b	31.6±5.9 b	0.32±0.14 a	0.08±0.03 a	0.40±0.17 a	0.15±0.04 a
P-HL-A (+)	32.1±5.7 b	67.9±6.2 b	32.1±6.2 b	0.32±0.07 a	0.09±0.02 a	0.41±0.09 a	0.15±0.03 a
P-HL-A (++)	37.6±1.0 b	62.4±5.5 b	37.6±5.5 b	0.40±0.22 a	0.11±0.04 a	0.52±0.24 a	0.17±0.08 a

Note: ± – standard deviation; alphabetic symbols indicate the difference between the options; [1] – water scarcity; [2] – relative turgescence; [3] – relative turgescence deficit

Source: compiled by the authors

Similar trends were recorded in the study by A. Bertaccini *et al.* (2014) on sesame (*Sesamum indicum*), where phytoplasma infection resulted in a statistically significant decrease in tissue water content by 11.4% compared to uninfected plants. Similar results were obtained in the study by L. Pavliuk *et al.* (2025), which showed that the water content in the leaf tissues of plants infected with PNRSV and PDV of the 'Nizhnist' cherry variety decreased by 20%. At the same time, when PDV was monoinfected in the 'Bohuslavka' variety and PNRSV in the 'Ksenia' variety, the water content in the infected samples was slightly higher by 1.4% and 5.7%, respectively, but these differences are statistically insignificant. According to the available literature data, this study is one of the few that evaluated the effect of phytoplasma on the water balance of plants. Due to the limited nature of such studies, unambiguous conclusions about the specific effects of the pathogen on different plant species remain difficult. However, it can be assumed that infection with phytoplasma has a more negative effect on plants of the genus *Prunus* compared to monoinfection with viral pathogens.

Water deficiency, as a rule, negatively affects the photosynthetic apparatus of plants, in particular, the content of chlorophylls and carotenoids. As part of the study, a decrease in the concentration of these pigments in infected plants was observed compared to the control. However, the results of the analysis of variance did not reveal statistically significant differences. In general, the degree of reduction in the content of photosynthetic pigments ranged from 11.9 to 33.3%, depending on the type of pigment and the level of infection. The chlorophyll a content in PP (potentially positive) and + (weakly positive) samples was reduced by 33.3% compared to the control, while in ++ (clearly positive) samples it was only 16.7% lower. A similar trend was found for chlorophyll b: in PP (potentially positive) and + (weakly positive) samples, a decrease of 27.3 and 18.2%, respectively, was observed, while in ++ (clearly positive) the content of chlorophyll b was at the level of control plants not infected with phytoplasma. Despite this, the total amount of green pigments (chlorophyll a + b) in all infected groups remained lower compared to the negative control. A similar trend was recorded in terms of carotenoid content: in PP (potentially positive) and + (weakly positive) samples, it was reduced by 28.6%, and in ++ (clearly positive) – by 19% compared to the control. A decrease in the level of pigments in samples with a higher concentration of the pathogen can be explained by the stress response of the plant, which occurs at the initial stages of infection. During this period, the most pronounced symptoms of the lesion and the negative impact of the pathogen on physiological processes, including photosynthesis. In the future, under conditions of prolonged exposure to the pathogen, the plant can partially adapt to the state of infection, which can reduce the severity of symptoms.

Studies by other researchers indicate a more pronounced negative effect of phytoplasma infection compared to the results recorded on the P-HL-A rhizome. Thus, according to S. Zafari *et al*. (2012), infected lime leaves showed a 70.9% decrease in chlorophyll a, 97.2% in chlorophyll b, and 98.7% in carotenoids. In addition, some studies indicate that the level of pigments in infected plants may depend on the age of the plant. For example, older apricot plants showed a 48.5% decrease in chlorophyll a, 50% decrease in chlorophyll b, and 43.1% decrease in carotenoids (Trempetić *et al*., 2025). Young plants reacted less strongly to infection: a decrease in chlorophyll a was 7.3%, chlorophyll b – 14.3%, and carotenoids – 3.2% compared to healthy plants. The timing of the study also played an important role, since a greater decrease in photosynthetic pigments was recorded in the second half of the growing season. Therefore, it can be assumed that the chlorophyll content on the rootstock under study has already reached the maximum point of decrease and, given the sampling period, no further decrease should be expected. Another confirmation of the negative effect of phytoplasma on the plant was the study by Y. Tan *et al*. (2015), who showed that when sweet cherries were infected with subgroup B phytoplasma (16srv-B), the chlorophyll content decreased by 51-56% depending on the type of pigment. The ratio of chlorophyll a/b in infected leaves was reduced, while the ratio of carotenoids to the total content of chlorophylls increased compared to the control. Similar results were obtained by M. Bertamini *et al*. (2002) in studies on grapes and apple trees, which also recorded a decrease in the level of photosynthetic pigments inplants infected by phytoplasma.

Thus, phytoplasma infection simultaneously worsened the water status and photosynthetic characteristics of plants, which negatively affected their survival rate and productivity. In some cases, its effect was more pronounced than with monoinfection with viral pathogens. This highlights the importance of systematic monitoring of the infectious load and the introduction of adaptive agrotechnical measures to reduce the stress effect of the pathogen and maintain stable crop productivity.

CONCLUSIONS

The study showed that phytoplasma infection significantly affects the water status and photosynthetic activity of P-HL-A rootstock plants. Even control, uninfected plants showed a water deficiency of 23.9%, which significantly exceeds the standard values for physiologically healthy plants (5-10%). Infected samples, depending on the degree of infectious load, had an even higher water deficit: in PP (potentially positive) and + (weakly positive) samples, it was 31.6-32.1%, and in ++ (clearly positive) – 37.6%. The relative turgescence (RT) in the control samples remained at 76.1%, indicating a slight water stress, while in infected plants RT decreased to 62.4-68.4%, indicating moderate or severe water deficiency.

Simultaneously, phytoplasma infection negatively affected the photosynthetic apparatus. Chlorophyll a in PP (potentially positive) and + (weakly positive) samples decreased by 33.3%, chlorophyll b – by 18-27%, and in ++ (clearly positive) samples, the decrease was less, which indicates partial adaptation of the plant to long-term exposure to the pathogen. The carotenoid content in PP (potentially positive) and + (weakly positive) samples decreased by 28.6 %, and in ++ (clearly positive) – by 19% compared to the control. These changes indicate that at the initial stages of infection, the plant experiences the greatest stress, but over time, partial compensation of damage is possible.

Thus, phytoplasma infection simultaneously disrupts the water balance and reduces the concentration of photosynthetic pigments, which negatively affects the physiological state, photosynthesis, and potential productivity of plants. The results highlighted the importance of monitoring the infectious load and implementing agrotechnical measures to minimise stress consequences, preserve rootstock survival, and maintain overall crop productivity. Further study of the combined effects of phytoplasma infection and abiotic stress on rootstock productivity and survival is important.

ACKNOWLEDGEMENTS

The authors express their gratitude to the VŠUO laboratory complement team for conducting laboratory diagnostics of plant material to detect phytoplasma.

FUNDING

The study was conducted with the support of the Ministry of Agriculture within the framework of the project "Fruit tree and berry crops MZE 62216/2022-13113/6.2.4".

CONFLICT OF INTEREST

None.

REFERENCES

[1] Ahmad, S.J.N., Farid, N., & Ahmad, J.N. (2019). Metabolic and physiological changes induced in *Sesamum indicum* infected by phytoplasmas. *Phytopathogenic Mollicutes*, 9(1), 137-138. doi: 10.5958/2249-4677.2019.00069.0.

[2] Arocha, Y., Antesana, O., Montellano, E., Franco, P., Plata, G., & Jones, P. (2007). "*Candidatus* Phytoplasma lycopersici", a phytoplasma associated with "hoja de perejil" disease in Bolivia. *International Journal of Systematic and Evolutionary Microbiology*, 57(8), 1704-1710. doi: 10.1099/ijs.0.64851-0.

[3] Asudi, G.O., Omenge, K.M., Paulmann, M.K., Reichelt, M., Grabe, V., Mithöfer, A., Oelmüller, R., & Furch, A.C.U. (2021). The physiological and biochemical effects on napier grass plants following napier grass stunt phytoplasma infection. *Phytopathology*, 111(4), 703-712. doi: 10.1094/PHYTO-08-20-0357-R.

[4] Bai, X., Correa, V.R., Toruño, T.Y., Ammar, E.-D., Kamoun, S., & Hogenhout, S.A. (2009). AY-WB phytoplasma secretes a protein that targets plant cell nuclei. *Molecular Plant-Microbe Interactions*, 22(1), 18-30. doi: 10.1094/MPMI-22-1-0018.

[5] Bertaccini, A., Duduk, B., Paltrinieri, S., & Contaldo, N. (2014). Phytoplasmas and phytoplasma diseases: A severe threat to agriculture. *American Journal of Plant Sciences*, 5(12), 1763-1788. doi: 10.4236/ajps.2014.512191.

[6] Bertamini, M., Muthuchelian, K., Grando, M.S., & Nedunchezhian, N. (2002). Effects of phytoplasma infection on growth and photosynthesis in leaves of field grown apple (*Malus pumila* Mill. cv. Golden Delicious). *Photosynthetica*, 40(1), 157-160. doi: 10.1023/A:1020156021629.

[7] Caglayan, K., Choueiri, E., & Rao, G.P. (2023). Graft and vegetative transmission of phytoplasma-associated diseases in Asia and their management. In A.K. Tiwari, K. Oshima, A. Yadav, S.A. Esmaeilzadeh-hosseini, Y. Hanboonsong & S. Lakhanpaul (Eds.), *Characterization, epidemiology, and management* (pp. 21-36). New York: Academic Press. doi: 10.1016/B978-0-323-91671-4.00014-9.

[8] Convention on Biological Diversity. (1992, June). Retrieved from https://surl.li/hlhcpe.

[9] Convention on the Trade in Endangered Species of Wild Fauna and Flora. (1976, March). Retrieved from https://surl.li/gazhha.

[10] El-Mageed, T.A.A., Rady, M.O.A., Semida, W.M., Shaaban, A., & Mekdad, A.A.A. (2021). Exogenous micronutrients modulate morpho-physiological attributes, yield, and sugar quality in two salt-stressed sugar beet cultivars. *Journal of Soil Science and Plant Nutrition*, 21, 1421-1436. doi: 10.1007/s42729-021-00450-y.

[11] EPPO Global Database. (2023). *"Candidatus Phytoplasma prunorum"*. Retrieved from https://gd.eppo.int/taxon/PHYPPR/distribution.

[12] Konup, A.I., Muliukina, N.A., & Konup, L.O. (2019). Detection of virus, bacterial and phytoplasmic diseases on vineyards of Odesa oblast. *Bulletin of Agricultural Science*, 4(4), 24-29. doi: 10.31073/agrovisnyk201904-04.

[13] Kuyan, V. (2016). Productivity of non-irrigated apple gardens on seedling and clonal rootstocks under the conditions of Ukrainian Forest-Steppe and Polissya. *Scientific Horizons*, 19(2), 149-156.
[14] Laxa, M., Liebthal, M., Telman, W., Chibani, K., & Dietz, K.-J. (2019). The role of the plant antioxidant system in drought tolerance. *Antioxidants*, 8(4), article number 94. doi: 10.3390/antiox8040094.
[15] Lee, S.-H., Kim, C.-E., & Cha, B. (2012). Migration and distribution of graft-inoculated jujube witches'-broom phytoplasma within a *Catharanthus roseus* plant. *The Plant Pathology Journal*, 28(2), 191-196. doi: 10.5423/PPJ.2012.28.2.191.
[16] Mekdad, A.A.A., Shaaban, A., Rady, M.M., Ali, E.F., & Hassan, F.A.S. (2021). Integrated application of K and Zn as an avenue to promote sugar beet yield, industrial sugar quality, and K-use efficiency in a salty and semi-arid agro-ecosystem. *Agronomy*, 11(4), article number 780. doi: 10.3390/agronomy11040780.
[17] Pavliuk, L., Riaba, I., Kryvoshapko, V., Bublyk, M., Bondarenko, P., & Udovychenko, K. (2025). Effect of virus infection on functional traits of *Prunus avium* and *Prunus cerasus* plants in nurseries. *Journal of Horticultural Research*, 33(1), 55-66. doi: 10.2478/johr-2025-0006.
[18] Shaaban, A., Al-Elwany, O.A.A.I., Abdou, N.M., Hemida, K.A., El-Sherif, A.M.A., Abdel-Razek, M.A., Semida, W.M., Mohamed, G.F., & El-Mageed, T.A.A. (2022). Filter mud enhanced yield and soil properties of water-stressed *Lupinus termis* L. in saline calcareous soil. *Journal of Soil Science and Plant Nutrition*, 22, 1572-1588. doi: 10.1007/s42729-021-00755-y.
[19] Singh, V., Kumar, S., & Lakhanpaul, S. (2018). Differential distribution of phytoplasma during phyllody progression in sesame (*Sesamum indicum* L.) under field conditions – an important consideration for effective sampling of diseased tissue. *Crop Protection*, 110, 288-294. doi: 10.1016/j.cropro.2017.01.016.
[20] Tan, Y., Wei, H.-R., Wang, J.W., Zong, X.-J., Zhu, D.-Z., & Liu, Q.-Z. (2015). Phytoplasmas change the source-sink relationship of field-grown sweet cherry by disturbing leaf function. *Physiological and Molecular Plant Pathology*, 92, 22-27. doi: 10.1016/j.pmpp.2015.08.012.
[21] Tedeschi, R., & Alma, A. (2006). *Fieberiella florii* (Homoptera: Auchenorrhyncha) as a vector of "*Candidatus* Phytoplasma mali". *Plant Disease*, 90, 284-290. doi: 10.1094/PD-90-0284.
[22] Trempetić, G., Zezulová, E., Nečas, T., Šnurkovič, P., & Kiss, T. (2025). Influence of "*Candidatus* Phytoplasma prunorum" on primary and secondary metabolites of apricots. *Plant Protection Science*, 61(3), 242-254. doi: 10.17221/128/2024-PPS.
[23] Valentová, L., Bohunická, M., Rejlová, M., Suchá, J., Nečas, T., Eichmeier, A., Cmejlova, J., & Cmejla, R. (2022). A survey of "*Candidatus* Phytoplasma pyri" isolates in the Czech Republic based on imp gene genotyping. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 50(1), article number 12602. doi: 10.15835/nbha50112602.
[24] Wang, R., Bai, B., Li, D., Wang, J., Huang, W., Wu, Y., & Zhao, L. (2024). Phytoplasma: A plant pathogen that cannot be ignored in agricultural production – research progress and outlook. *Molecular Plant Pathology*, 25(2), article number e13437. doi: 10.1111/mpp.13437.
[25] Zafari, S., Niknam, V., Musetti, R., & Noorbakhsh, S.N. (2012). Effect of phytoplasma infection on metabolite content and antioxidant enzyme activity in lime (*Citrus aurantifolia*). *Acta Physiologiae Plantarum*, 34, 561-568. doi: 10.1007/s11738-011-0855-0.

Лілія Павлюк
Доктор філософії, науковий співробітник
Науково-дослідний і селекційний інститут помології «Головоуси»
50801, вул. Головоуси, 129, с. Головоуси, Чеська Республіка
https://orcid.org/0000-0002-5357-9322

Міхаела Марклова
Інженер, науковий співробітник
Науково-дослідний і селекційний інститут помології «Головоуси»
50801, вул. Головоуси, 129, с. Головоуси, Чеська Республіка
https://orcid.org/0009-0001-0879-359X

Оцінка фізіологічного стану підщепи P-HL-A за умов інфікування фітоплазмою

Анотація. Актуальність дослідження обумовлена значним впливом фітоплазмових інфекцій на продуктивність та фізіологічний стан підщеп садових культур, що створює ризики для приживлюваності та розвитку бруньок під час щеплення та їхнього подальшого росту. Метою роботи було оцінити фізіологічну придатність підщепи P-HL-A за умов потенційного або наявного інфікування фітоплазмою у період проведення окулірування. Для досягнення цієї мети застосовувалися методи молекулярної діагностики, а саме полімеразної ланцюгової реакції (ПЛР) в реальному часі для визначення наявності патогену, аналіз тургесцентності листкових тканин для оцінки водного дефіциту, а також спектрофотометричне визначення фотосинтетичних пігментів (хлорофілів та каротиноїдів). Було досліджено зміни водного режиму та функціонального стану фотосинтетичного апарату підщеп P-HL-A залежно від ступеня інфікування. Було встановлено, що фітоплазмове ураження спричиняє водний дефіцит у межах 31,6-37,5 % та зниження відносної тургесцентності до 62,4-68,4 %, що свідчило про розвиток помірного водного стресу. Було проаналізовано вміст фотосинтетичних пігментів, який знижувався на 11,9-33,3 % залежно від типу пігменту та рівня інфекційного навантаження. Було узагальнено, що початковий вплив патогену проявлявся зниженням тургору клітин та фотосинтетичної активності, що може негативно впливати на приживлюваність бруньок під час щеплення. Практична цінність роботи полягає в тому, що отримані результати можуть бути використані садівниками, агрономами та науковцями у розсадниках та дослідних станціях для оптимізації агротехнічних заходів, контролю фітоплазмових інфекцій та підвищення ефективності розмноження плодових культур

Ключові слова: водний дефіцит; фотосинтез; тургесцентність клітин; хлорофіл; каротиноїди