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THE RESPONSE OF GRAPEVINE TO WATER STRESS IN THE PRESENCE OF VIRUS INFECTION

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INTRODUCTION

Grapevine (*Vitis spp*.) represents one of horticultural crop most widely cultivated in the temperate climates and an economically very important fruit crops at mondial level.

Unfortunately, as a perennial plant, in addition to other pathogens, grapevine potentially can host many viral entities, the most aggressive limiting factors of the quality and quantity of grapes, plant development processes and vineyards lifetime. Assessing the effects of viruses and viral diseases is not as easy as one might think, as the severity of symptoms varies from one virus to another (even depending on the virulence of the strain), the genotype and age of the infected grapevine, and environmental conditions as abiotic stress factors (Manninni, 2003; Martelli and Boudon-Padieu, 2006; Mannini and Digiaro, 2017).

Currently, approximately 80 viruses belonging to different families have been reported infecting grapevines. Of these, 31 viruses having worldwide economic importance are associated with the four major disease complexes known as: grapevine leafroll (5 viruses), rugose wood complex (6 viruses), infectious degeneration (12 Eurasian/European/Mediterranean *Nepoviruses*) and decline (4 American *Nepoviruses*), and fleck diseases (4 viruses) (Martelli, 2017; 2018; Fuchs, 2020).

Both viral diseases (as biotic stress factor) and drought (one of the biggest abiotic stress factors) are limiting factors of grapevine production (Malossini et al., 2003). The influence of stress caused by viral infection (Cui et al.., 2015) or drought (Zhu, 2002) were relatively well presented in terms of plant growth and development, photosynthetic capacity, production. However, studies on their combined effects have been limited.

Field-grown plants are simultaneously exposed to abiotic and biotic stress factors. Abiotic stress has been shown to alter the resistance or tolerance of plants to pathogens. Similarly, biotic stress alters the host's resistance/tolerance to abiotic stress. Therefore, the response of the plant to a single stress factor differs from that to several stress factors and the concurrent action of multiple stress can induce complex plant responses (Suzuki et al., 2014).

The study deals with the response of grapevine plants infected with different viruses to water deficit, both in vineyard and controlled setting.

MATERIALS AND METHOD

Grapevine plants infected with different viruses were studied in the field (Tanne et al. 1996; Gutha et al., 2010; Gambino et al., 2012; Moutinho-Pereira et al. 2012; Repetto et al., 2012; Zahavi et al., 2012; Verdegaal P., 2015; El Aou-ouad, 2017; Couzzo et al., 2018; Levin and Achala (2020), in greenhouse (Pantaleo et al., 2016; Guță and Buciumeanu, 2020), and *in vitro* conditions (Tanne et al. 1996; Cui et al., 2015) to assess their behaviour to an abiotic stress factor (water deficit) in combination with a biotic stress factor (the presence of virus infection).

Most studies reviewed in the paper have been conducted on plants affected by leafroll disease, being the most widespread and economically damaging grapevine virus disease in all growing region of the world (Naidu et al., 2014).

RESULTS AND DISCUSSION

Grapevine is a model plant to study plant–virus interactions in woody species in both controlled and field conditions (Perrone et al., 2017).

The damages caused by grapevine leafroll disease varies depending on growing conditions, clones, location, plant age, rootstock, virus or combination of viruses infecting plants, environmental conditions (Pesqueira et al., 2012).

In the field, grapevine plants of red cultivars affected by leafroll disease showed symptoms earlier when they were stressed by deficit irrigation. Based on this observation, a non-grafting protocol was described that allowed the rapid expression of symptoms of infection with *Grapevine leafroll-associated virus 3* (GLRaV-3) on *in vitro* grown microshoots by the addition of 4% sorbitol to induce water stress (water deficit) in virus disease affected shoots. Thus, the leafroll symptoms were expressed after 4-8 weeks of *in vitro* culture, depending on the grapevine genotype (Tanne et al., 1996). Saline stress and drought induced by NaCl and polyethylene glycol (PEG) 8000 may improve *in vitro* biological indexing of GLRaV-3 in red grapevine varieties. The expression of viral symptoms was more obvious and safer when *in vitro* plants were stressed with NaCl than with PEG. The techniques would have potential applications for GLRaV-3 indexing of red grapevine varieties (Cui et al., 2015).

Another study concluded that the irrigation of grapevine plants (Cabernet Sauvignon variety) affected by leafroll disease influenced the expression of symptoms, after the formation of fruit strongly irrigated vines showing more pronounced symptoms than those poorly irrigated (Zahavi et al., 2012).

The combination of GLRaV-3 infection with water stress decreased most of the physiological parameters in the grapevines (Malvasia de Banyalbufar and Giro ros varieties) but it did not further increase the effects on plant growth or parameters regarding the gas exchange at the level of the leaves, as compared to the individual water stress. At the metabolic level, the responses to the combined stress were specific and they were not quantitatively anticipated from the sum of the responses to each unique stress. Specific adjustment of respiratory metabolism may explain the maintenance of carbon balance in the leaves and the growth of the grapevine under conditions of combined stress (El Aou-ouad, 2017).

Grapevine rupestris stem pitting-associated virus (GRSPaV) caused a profound change in the expression of genes involved in hormones metabolism, transcripts related to the biosynthetic pathways of ethylene, cytokinins, gibberellins, β-indolylacetic acid have been activated, and other auxin-signaling genes have been repressed. In addition, a significant overlap of cellular responses was observed between GRSPaV infection and abiotic stress, such as water deficit and salinity (Gambino et al., 2012).

The irrigation and application of proper fertilizers reduced the stress on the grapevine and helped to decrease the negative effect of nematodes on the roots (e.g., *Xiphinema index, X. americanum,* vectors for *Grapevine fanleaf virus* – GFLV (Verdegaal, 2015).

Surprisingly, *Grapevine leafroll-associated viruses 1 and 3* (GLRaV-1 and GLRaV-3) have been shown to increase the intrinsic efficiency of water use in the Touriga Nacional genotype under field conditions (Moutinho-Pereira et al. 2012). Also, the interaction between GRSPaV and grapevine appears to have improved the plant's tolerance to drought in greenhouse conditions (Pantaleo et al., 2016).

Regarding the eco-physiological performance, the presence of double infection with GLRaV-1 and *Grapevine virus A* (GVA) severely penalized all parameters involved, as compared to healthy grapevines: photosynthesis, transpiration and the concentration of substomatal CO_2. The reduction in photosynthetic activity has been evident starting from the early assessment (June) and it has increased during the summer. When only GVA infection was present, the reduction of photosynthesis was delayed until July and became apparent in August, when climatic conditions caused water stress. However, the difference between GVA-infected and healthy grapevines in the physiological behavior of plants was less significant as compared to that involving double viral infection (Couzzo et al., 2018).

Grapevine fleck virus (GFkV) infection induced fiziological modification in potted grapevine belonging to a Tămâioasă românească selection, more pronounced than in healthy plants during the progressive water deficit, in greenhouse conditions (Guță and Buciumeanu, 2020).

Some virus-induced alterations may partly explain grapevine reduced susceptibility to fungal infection. GLRaV-3 causes several detrimental effects in grapevine determined by a number of molecular and physiological changes which may inhibit the fungal pathogenicity. The red color of symptomatic leaves in GLRaV-3-infected plants may be due to the accumulation of *de novo* synthetized anthocyanins and could consider an up-regulation of genes involved in their biosynthesis (Gutha et al., 2010). Due to the fact that stilbene amount and defense-related gene expression increased in virus-infected plants, can explain why grapevines infected with GLRaV-3 showed an increased resistance in the field to the fungal pathogen *Plasmopara viticola* (Repetto et al., 2012).

A study performed by Levin and Achala (2020) showed that the application of water deficit to grapevine infected with *Grapevine Red Blotch Virus* (GRBV) did not improve the quality of Pinot noir grapes. In some cases, water deficit can reduce fruit quality, but this may depend on the age and the water severity itself. Biologically, the study confirmed that the negative effects of the disease produced by GRBV are strongly controlled by the virus, probably at the molecular level, and shows that this control cannot be reversed by any water deficit. The virus presence changes the carbon metabolism from the grapevine leaf to the whole plant level, which in turn negatively influences secondary metabolism on short-term and possibly the long-term grapevine productivity. Therefore, it is not known whether water deficit can amplify or exacerbate the negative effects of the disease on fruit quality or they can be attenuated.

The indirect effects of climate change on the resources and ecosystems conditioning an activity lead in viticulture to a level of incertitude which applies in the cases of water supply, pests and diseases (Viguie et al., 2014).

These two stress factors (drought and viral diseases) are often found simultaneously in many grapevine growing areas of the world. Thus, a better understanding of the effects of combining abiotic stress with biotic stress is of great importance and would allow the orientation of management strategies to ensure the sustainable development of agricultural production.

CONCLUSIONS

The works regarding the reaction of virus-infected grapevine in water stress conditions reviewed in this paper have been conducted on plants having different virus infection as: *Grapevine leafroll-associated virus 1 and 3, Grapevine rupestris stem pitting-associated virus, Grapevine virus A, Grapevine fanleaf virus, Grapevine fleck virus, Grapevine Red Blotch Virus*. Most of the studies referred to the leafroll disease, being the most widespread and economically detrimental grapevine virus disease in all growing region of the world.

Both viral diseases (as biotic stress factor) and drought (one of the most important abiotic stress factors) often found simultaneously in many grapevine growing areas of the world.

The behaviour of the grapevine to a single stress factor differs from that to several stress factors and the simultaneous action of multiple stress can induce complex plant responses.

In vitro conditions, the expression of viral symptoms in plants with *Grapevine leafroll-associated virus* 3 infection was more obvious when the grapevines of red grape varieties were saline and drought stressed.

Better understanding the effects on grapevine to the combining of abiotic (environmental) with biotic ones stress factors (diseases, pests) is of high importance and would allow the orientation of management strategies to ensure the durable development of viticultural production, under the conditions of climate changes.

ABSTRACT

Grapevine (*Vitis spp*.) is a model plant for the plant-virus interactions studies of woody species in both controlled (greenhouse, *in vitro*) and field trials. Grapevine is potentially infected by numerous viral entities. A few studies have been performed on pathogenic viruses infecting this crop, in some environmental conditions (water stress) and in different grapevine genotype - virus combinations. These works, still in quite reduced number, highlights the importance of deepening the biology underlying the plant-virus interactions.

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REFERENCES

1. CUI Z.H., BI W.L., CHEN P., XU Y., WANG Q.C., 2015 - Abiotic stress improves *in vitro* biological indexing of Grapevine leafroll-associated virus-3 in red grapevine cultivars, Australian Journal of Grape and Wine Research, 21, pp. 490–495. doi: 10.1111/ajgw.12146.
2. CUOZZO D., CHITARRA W., FERRANDINO A., GRIBAUDO I., GAMBINO G., MANNINI F., 2018 - Field performances and grape quality of the same clone of 'Nebbiolo' (*Vitis vinifera* L.) when infected by GLRaV-1+GVA, GVA or healthy, Proceedings of the 19th Congress of ICVG, Santiago, Chile, April 9-12, 2018, pp. 140-141.
3. EL AOU-OUAD H., 2017 - Interactive effects of grapevine leafroll associated virus-3 (GLRaV-3) and water stress on the gas exchange, water use efficiency, plant hydraulics and metabolism in local grapevine cultivars, PhD Thesis, University of Balearic Islands, 209 pp.
4. FUCHS M., 2020 - Grapevine viruses: a multitude of diverse species with simple but overall poorly adopted management solutions in the vineyard, Journal of Plant Pathology, 102, pp. 643-653. doi: 10.1007/s42161-020-00579-2.
5. GAMBINO G., CUOZZO D., FASOLI M., PAGLIARANI C., VITALI M., BOCCACCI P, PEZZOTTI M., MANNINI F., 2012. Effects of Grapevine Rupestris Stem Pitting-Associated Virus on *Vitis vinifera* L., Proceedings of the 17th Congress of ICVG, Davis, CA, USA, October 7-14, 2012, pp. 90-91.
6. GUTHA L.R., CASASSA L.F., HARBERTSON J.F., NAIDU R.A., 2010 - Modulation of flavonoid biosynthetic pathway genes and anthocyanins due to virus infection in grapevine (*Vitis vinifera* L.) leaves, BMC Plant Biology, 10, pp. 187.
7. GUȚĂ I.-C., BUCIUMEANU E.-C., 2020 - The behavior of grapevine under virus infection and drought stress combination, AgroLife Scientific Journal, 9(2), pp. 131-138, ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718.
8. LEVIN A.D., ACHALA N. KC., 2020 - Water Deficits Do Not Improve Fruit Quality in Grapevine Red Blotch Virus-Infected Grapevines (*Vitis vinifera* L.), Frontiers in Plant Science, 11, pp. 1292. doi: 10.3389/fpls.2020.01292.
9. MALOSSINI U., CICCOTI A.M., GRAGAGNA P., VINDIMIAN M.E., MOSER S., VERSINI G., NICOLINI G., 2003 - Changs in agronomical and oenological performances of clones of the grapevine cv. Gewurtztraminer after Grapevine Fanleaf virus elimination by heat therapy, Proceedings of the 14th Congress of

ICVG, Locorotondo (Bari), Italy, 12-17 September 2003, pp. 252-253.
10. MANINNI F., 2003 - Virus elimination in grapevine and crop performance. Extended abstracts 14th ICVG Meeting, 12-17 September 2003, Locorotondo (Bari), Italy, pp. 234-239.
11. MANNINI, F., DIGIARO, M., 2017 - The Effects of Viruses and Viral Diseases on Grapes and Wine. In: Meng, B., Martelli, G., Golino, D., Fuchs, M. (eds) Grapevine Viruses: Molecular Biology, Diagnostics and Management, Springer, Cham. https://doi.org/10.1007/978-3-319-57706-7_23, pp. 453-482.
12. MARTELLI G.P., 2017 - An Overview on Grapevine Viruses, Viroids, and the Diseases They Cause. In: Meng B., Martelli G., Golino D., Fuchs M. (eds), Grapevine Viruses: Molecular Biology, Diagnostics and Management. Springer, Cham. https://doi.org/10.1007/978-3-319-57706-7_2, pp. 31-46.
13. MARTELLI G.P., 2018 - Where grapevine virology is heading to, Proceedings of the 19th Congress of ICVG, Santiago, Chile, April 9-12, 2018, pp. 10-15.
14. MARTELLI G.P., BOUDON-PADIEU E. (Eds.), 2006 - Options méditerranéenes. Serie B: Studies and Research 55, Bari, CIHEAM (Centre International de Hautes Etudes Agronomique Méditerranéen), Italy/ISSN-1016-1228.
15. MOUTINHO-PEREIRA J., CORREIA C.M., GONCALVES B., BACELAR E.A., COUTINHO J.F., FERREIRA H.F., LOUSADA J., LAND CORTEZ M.I., 2012 - Impacts of leafroll-associated viruses (GLRaV-1 and -3) on the physiology of the Portuguese grapevine cultivar 'Touriga Nacional' growing under field conditions, Frontiers in *Plant Science,* 160, pp. 237-249.
16. NAIDU R., ROWHANI A., FUCHS M., GOLINO D.A., 2014 - Grapevine Leafroll: A Complex Viral Disease Affecting a High-Value Fruit Crop. Plant disease, 98(9), pp. 1172-1185.
17. PANTALEO V., VITALI M., BOCCACCI P., MIOZZI L., CUOZZO D., CHITARRA W., MANNINI F., LOVISOLO C., GAMBINO G., 2016 - Novel functional microRNAs from virus-free and infected *Vitis vinifera* plants under water stress, Scientific Report, 6, 1-14. DOI: 10.1038/srep20167.
18. PESQUEIRA A.M., GARCÍA-BERRIOS J.-J., BARRASA M., CABALEIRO C., 2012 - Economic Impact of Leafroll Disease in Vineyards of the Cultivar Albariño in Rías Baixas (Spain), Proceedings of the 17th Congress of ICVG, Davis, CA, USA, October 7-14, 2012, pp. 57–58.
19. REPETTO O., BERTAZZON N., DE ROSSO M., MIOTTI L., FLAMINI R., ANGELINI E., BORGO M., 2012 - Low susceptibility of grapevine infected by GLRaV-3 to late *Plasmopara viticola* infections: towards understanding the phenomenon, Physiological and Molecular Plant Pathology, 79, pp. 55–63.
20. SUZUKI N., RIVERO R.M., SHULAEV V., BLUMWALD E., MITTLER R., 2014 - Abiotic and biotics tress combinations, New Phytologist, 203, pp. 32–43. doi:10.1111/nph. 12797.
21. TANNE E., SPIEGEL-ROY P., SHLAMOVITZ N., 1996 - Rapid *in vitro* indexing of grapevine viral diseases: the effect of stress-inducing agents on the diagnosis of leafroll, Plant Disease, 80, pp. 972-974.
22. VERDEGAAL P., 2015. Nematodes in grapes. https://www.lodigrowers.com/wp-content/uploads/2015/02/Nematodes-in-Grapes2015LWC1.pdf. (accessed April 12, 2022).
23. VIGUIE V., LECOCQ F., TOUZARD J.M., 2014 - Viticulture and Adaptation to Climate Change. Journal International des Sciences de la Vigne et du Vin, pp.55-60 https://hal-enpc.archives-ouvertes.fr/hal-00982086/document (accessed April 12, 2022).
24. ZAHAVI T., MAWASS M., NAOR A., GAL Y., PERES M., ROSHANSKY I., NELEVITZKY R., SAPIR G., CRANE O., 2012 - Effects of Irrigation on Leafroll Symptom Development in Cabernet Sauvignon Vines, Proceedings of the 17th ICVG, Davis, California, USA, October 7-14, 2012, pp. 162-136.
25. ZHU J., 2002 - Salt and drought stress signal transduction in plants, Annual Review of Plant Biology, 53, pp. 247–273.

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