



EXTENDED ABSTRACT

Studying PIWIs in three dimensions: agronomic, economic and ecological evaluation of 14 fungus-tolerant cultivars in Luxembourg

Kristina Heilemann¹, Christopher Simon², Marie-Sophie Roderich³,
Claudio Petucco³, Daniel Molitor¹, Marco Beyer¹

*Corresponding author: kristina.heilemann@list.lu

¹ Luxembourg Institute of Science and Technology (LIST), Environmental Sensing and Modelling (ENVISION) research unit, 41, rue du Brill, L-4422 Belvaux, Luxembourg

² Institut viti-vinicole (IVV), Section Viticulture, 8, rue Nic. Kieffer, L-5551 Remich, Luxembourg

³ Luxembourg Institute of Science and Technology (LIST), Environmental Sustainability Assessment and Circularity (SUSTAIN) research unit, 5, Avenue des Hauts Fourneaux, L-4362, Esch-sur-Alzette, Luxembourg

Keywords: fungus-tolerant varieties, Luxembourgish Moselle, ecological impact, black rot

ABSTRACT

Growing fungus-tolerant cultivars (PIWIs) enables to reduce the fungicide use by 50-80 %. PIWIs have the potential to address climate change adaptation and mitigation simultaneously. However, despite the obvious advantages of PIWI cultivation only 0.5% of the viticultural area in Luxembourg is planted with PIWIs at present. Consequently, the present investigations aimed at addressing knowledge and experience gaps of PIWI cultivation and quantifying their economic and ecological advantages.

The project PIWI³ characterizes 14 PIWI cultivars in three dimensions: (1) agronomically, (2) economically and (3) ecologically for the years 2023-2025. White and red PIWIs are compared with the traditional cultivars Rivaner and Pinot noir, respectively. The present study focuses on the susceptibility of selected cultivars towards major fungal diseases such as powdery and downy mildew, gray mould and black rot. Furthermore, susceptibility towards *Drosophila suzukii* is monitored as well as yield, the phenological development and maturity progress. To evaluate the ecological impact, a life cycle assessment is undertaken and costs per ha are evaluated.

Weather conditions in 2024 resulted in severe disease pressure. Disease severities recorded for downy and powdery mildew were significantly lower in PIWIs compared with traditional cultivars but also differed at low levels. High disease severities of blackrot were observed in the cvs Sauvignac, Johanniter and Cabernet blanc. The onset of *Botrytis cinerea* epidemics was observed later in PIWI cultivars than in the traditional cultivars. The cvs Pinotin, Calardis blanc and Villaris showed the highest bunch rot disease severities prior to harvest in 2024. However, in cv Pinotin bunch rot symptoms were mainly caused by sour rot, caused by infestation with *D. suzukii*.

Phenological development differed widely among the PIWI cultivars. The PIWIs studied here were generally ripening earlier compared to the traditional cultivars Rivaner and Pinot noir. The earliest cultivar reaching full maturity was cv Solaris. The highest average yield was observed for cv Bronner.

Cultivation of PIWIs reduced the overall environmental impact by two-thirds, compared to the cultivation of traditional cultivars. The reduced need of pesticide applications decreased the annual costs of plant protection by 56-62%, making PIWIs a viable and sustainable alternative for winegrowers.

INTRODUCTION

Grapevine physiology, growth, yield and berry composition are mainly driven by climatic conditions (Santos et al., 2020). Consequently, viticulture is highly affected by changes in precipitation patterns and the higher frequency of extreme weather events caused by climate change (IPCC, 2021). Furthermore, the “Farm to fork” strategy within the European Green Deal implies the target of reducing pesticides by 50% until 2050 posing further challenges for growers in maintaining yields. Both challenges might be addressed by the cultivations of fungus-tolerant cultivars (German=PIWIs), which allow reducing the use

of pesticides by 50-80 % as they carry several resistance loci, leading to a reduced susceptibility towards major fungal diseases (Töpfer & Trapp, 2022). PIWIs have the potential (i) to address climate change adaptation and mitigation simultaneously and (ii) play a major role in future viticultural strategies. The cultivation of PIWIs reduces the economic risk for winegrowers, especially under more extreme weather conditions, such as extended rain periods in summer leading to high disease pressure. Likewise, growing PIWI cultivars reduces greenhouse gas emissions by the reduction of fungicide applications and therefore saving



tractor passages and energy demand for fungicide synthesis and transport. However, despite the obvious positive effects of PIWI cultivation presently only 0,5% of the viticultural area in Luxembourg is covered with PIWIs (Anonymous, 2023). Consequently, present investigations aimed at filling knowledge and experience gaps of PIWI cultivation under local conditions and quantifying their economic and ecological advantages.

MATERIAL AND METHODS

Within the project, 10 white and 4 red PIWI cultivars grown at the Institut viti-vinicole in Remich, planted between 2010 and 2017 and grafted mainly on the rootstock SO4 are characterized. The white PIWI cultivars were: Bronner, Cabernet blanc, Calardis blanc, Helios, Johanniter, Muscaris, Sauvignac, Solaris, Souvignier gris and Villaris. The red PIWI cultivars were Cabertin, Divico, Pinotin and Cabaret noir. Plants were trained to a vertical shoot positioning system (VSP) with 8 shoots per vine. Fungicide treatments were carried out at BBCH 68 and BBCH 71-75 for the PIWI cultivars. Traditional cultivars Rivaner and Pinot noir were treated 12-14 times (Rivaner and Pinot noir with usual fungicide application - UFA), depending on the annual meteorological conditions. Additionally, two rows of each of the traditional cultivars were treated in the same way as the PIWI cultivars (Rivaner and Pinot noir with PIWI fungicide application – PFA, 2 sprays). Unless stated otherwise, all PIWI cultivars are compared to Rivaner. The fungicide regime consisted of applications of sulfur, copper and phosphonate-based products.

The present study focuses on the susceptibility of the different cultivars towards major fungal diseases such as powdery and downy mildew, *Botrytis cinerea* and black rot. Assessments took place at bi-to triweekly intervals, examining clusters and leaves (n=100) of both sides of the canopy. Disease severity was determined according to the EPPO guideline PP1/17(3), classifying the observed symptoms in seven classes (0%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, 76-100%). The development of *Botrytis cinerea* was recorded weekly by assessing 50-100 grapes from both sides of the canopy, according to the EPPO guideline described above. To follow

RESULTS AND DISCUSSION

The total rainfall in the vegetation period of 2024 in Remich (April-October) was 601.6 mm (www.agrimeteo.lu - Administration des Services techniques de l'agriculture), leading to high infection severities of all assessed fungal diseases. Recorded disease severities of downy mildew on grapes ranged in 2024 from 0,0% (Divico, Bronner, Sauvignac, Villaris, Solaris and Muscaris) to 2.6% (Souvignier gris). Means of 2023 and 2024 showed that the cultivated PIWIs are hardly susceptible to downy mildew. When treated two times as the PIWIs, the traditional cultivar Rivaner UFA had an average disease severity of 16.9 % on grapes and Rivaner PFA had a disease severity of 33,5%. Symptoms of powdery mildew on grapes were not detected for the PIWI cultivars except for Muscaris (0.1%), Cabernet

The project PIWI³ characterizes 14 PIWI cultivars in three dimensions: (1) agronomical, (2) economical and (3) ecological performance for the years 2023-2025. PIWIs are compared to the traditional cultivars Rivaner and Pinot noir for white and red wine cultivars, respectively. After the three-year project duration, major results will be published online as factsheets for each of the 14 cultivars to support growers in their decision-making process.

the maturation progress, berry samples (n=100) were taken weekly of each cultivar on both sides of the canopy. Cultivars were harvested separately to assess average yield.

Phenological stages according to Lorenz et al. (1995) were recorded when 50% of the vines or organs exhibited the stage. Observations of phenological development took place twice a week.

Susceptibility towards *Drosophila suzukii* was monitored starting from 70° Oechsle (°Oe) until harvest. For the assessment of *D. suzukii* infestation, 50 berries were taken from the red and reddish cultivars by randomly picking berries from 15 different grapes. Eggs of *D. suzukii* were counted under a binocular.

To evaluate the economic and ecological impact of PIWI cultivars in comparison to traditional cultivars a life cycle assessment methodology was applied to Sauvignac and Cabaret noir as well as Rivaner and Pinot noir, with the traditional fungicide treatment. Input data was defined based on literature research to calculate the impact of 1kg of produced grapes (functional unit). Input data was delivered either by the IVV or reference data was used of the Luxembourgish field machine cooperative “Maschinenring” and of the recommendations “Environmental Footprint of the European Commission”.

The economic evaluation considered the following cost components per ha: pesticide cost, fertilizer cost, diesel cost and operator cost. The cost per ha was compared between PIWI (Sauvignac and Cabaret noir) and traditional cultivars (Rivaner and Pinot noir UFA).

blanc (1.6%) and Cabertin (3.8%) in 2024. Rivaner UFA had a disease severity of 5,3%. On grapes, cvs Sauvignac, Johanniter and Cabernet blanc showed high disease severities of black rot in 2024 (14.2%, 15.5% and 17.4%, respectively), while other PIWI cultivars had no/low symptoms, as well as Rivaner. The onset of *Botrytis cinerea* epidemic was observed later in most PIWI cultivars than in the traditional cultivars. PIWIs reached a disease severity of 1% at higher sugar content than Rivaner. Comparing the PIWIs, the cvs Calardis blanc, Pinotin and Helios have the lowest maturity level when 1% Botrytis is reached. However, in cv Pinotin bunch rot symptoms were mainly caused by sour rot, due to the infestation with *D. suzukii*. Pinotin can be considered susceptible towards *D. suzukii*.

The phenological development differed widely among the PIWI cultivars. Some are very early in budburst, like for example Muscaris and Solaris, others are late like Helios and Villaris. These differences can be used in cultivar choice regarding the late frost risk. The assessed PIWIs are generally ripening earlier compared to the traditional cultivar Rivaner. The earliest cultivar to ripen was cv Solaris.

The highest average yield was observed for cv Bronner in both years with an average of 15157 kg/ha. Other PIWI cultivars produced less yield than Rivaner UFA, but more yield than Rivaner PFA.

CONCLUSIONS

The characterization of 14 PIWIs in three dimensions might lower the barriers for growing alternative cultivars in Luxembourg and in general, filling the knowledge and experience gap of PIWI cultivation under local conditions and highlighting the economic and ecological advantages. A characterization of the sensory attributes of PIWI wines is envisaged in a follow-up project.

ACKNOWLEDGEMENTS

We thank the Ministry of Agriculture, Food and Viticulture for funding the PIWI³ project and the Institut viti-vinicole for access to their vineyards as well as the entire IVV team for supporting us in the management of the vineyards.

REFERENCES

- Anonymous. (2023). *Das Weinjahr 2022 und seine Ernteergebnisse*. Veröffentlichung der Abteilung Weinbau des Weinbauinstitutes in Remich. In press.
- IPCC. (2021). *The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, p. 2391). Cambridge. <https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/>
- Lorenz, D. H., Eichhorn, K. W., Bleiholder, H., Klose, R., Meier, U., & Weber, E. (1995). Growth stages of the grapevine: Phenological growth stages of the grapevine (*Vitis vinifera* L. ssp. *Vinifera*)—Codes and descriptions according to the extended BBCH scale. *Australian Journal of Grape and Wine Research*, 1(2). <https://doi.org/10.1111/j.1755-0238.1995.tb00085.x>
- Santos, J. A., Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., Dinis, L. T., Correia, C., Moriondo, M., Leolini, L., Dibari, C., Costafreda-Aumedes, S., Kartschall, T., Menz, C., Molitor, D., Junk, J., Beyer, M., & Schultz, H. R. (2020). A review of the potential climate change impacts and adaptation options for European viticulture. *Applied Sciences*, 10(9). <https://doi.org/10.3390/app10093092>
- Töpfer, R., & Trapp, O. (2022). A cool climate perspective on grapevine breeding: Climate change and sustainability are driving forces for changing varieties in a traditional market. *Theoretical and Applied Genetics*, 135(11), 3947–3960. <https://doi.org/10.1007/s00122-022-04077-0>

The cultivation of PIWIs reduced the overall environmental impact by two-thirds, compared to the cultivation of traditional cultivars. The impact per kg of grapes was higher across all environmental categories for the traditional cultivars, with major contributions from freshwater ecotoxicity, mainly resulting from the higher pesticide use. Through the pesticide reduction the costs for plant protection per ha could be reduced by 56-62% per ha when cultivating PIWIs.

