



Integrative Statistical Approaches to Evaluate Fungicide Efficacy Against *Botrytis cinerea* in the White Grape Variety *Grenache blanc*

Gligor Bojkov^{1*}, Emilija Arsov¹, Sasa Mitrev¹

¹Faculty of Agriculture, Department for Plant and Environmental Protection, Goce Delcev University, UNILAB laboratory, Stip, R. North Macedonia

* gligorbojkov@yahoo.com

Abstract

The present study evaluated the effectiveness of different fungicidal treatments against *Botrytis cinerea* in *Vitis vinifera* cv. *Grenache blanc* using agro-climatic data were obtained from the ERA5-Ag reanalysis dataset, providing high-resolution, bias-corrected meteorological variables. Bunches wetness duration was used as a key predictor of infection. Three treatments were tested: control (untreated variant), the synthetic fungicide combination fludioxonil + cyprodinil, and the biological formulation *Bacillus amyloliquefaciens*.

Introduction

The long-term cultivation of grapevines in wine-growing regions necessitates the evaluation of fungicides efficacy immediately before harvest, primarily to prevent the development of *B. cinerea*, which can deteriorate grape quality and negatively affect wine production. Therefore, a study on fungicide efficacy was conducted in experimental grapevine plots located in Sopot 2, Kavadarci, Republic of North Macedonia, planted with the *Grenache blanc* variety.

Result and Discussion

The relationship between bunch wetness duration (LW) and disease risk exhibited a characteristic sigmoidal (logistic) pattern (figure 1). At low wetness durations (<3 h), infection probability remained negligible. A sharp increase in risk occurred between 4 and 8 hours, reflecting key biological processes such as spore germination and host penetration. Beyond 10 hours, the risk approached saturation, indicating near-optimal conditions for *Botrytis cinerea* infection. The inflection point, occurring at approximately 6 hours, represents a critical threshold for disease development. The Risk Disease parameter was derived from ERA5-Ag climate data

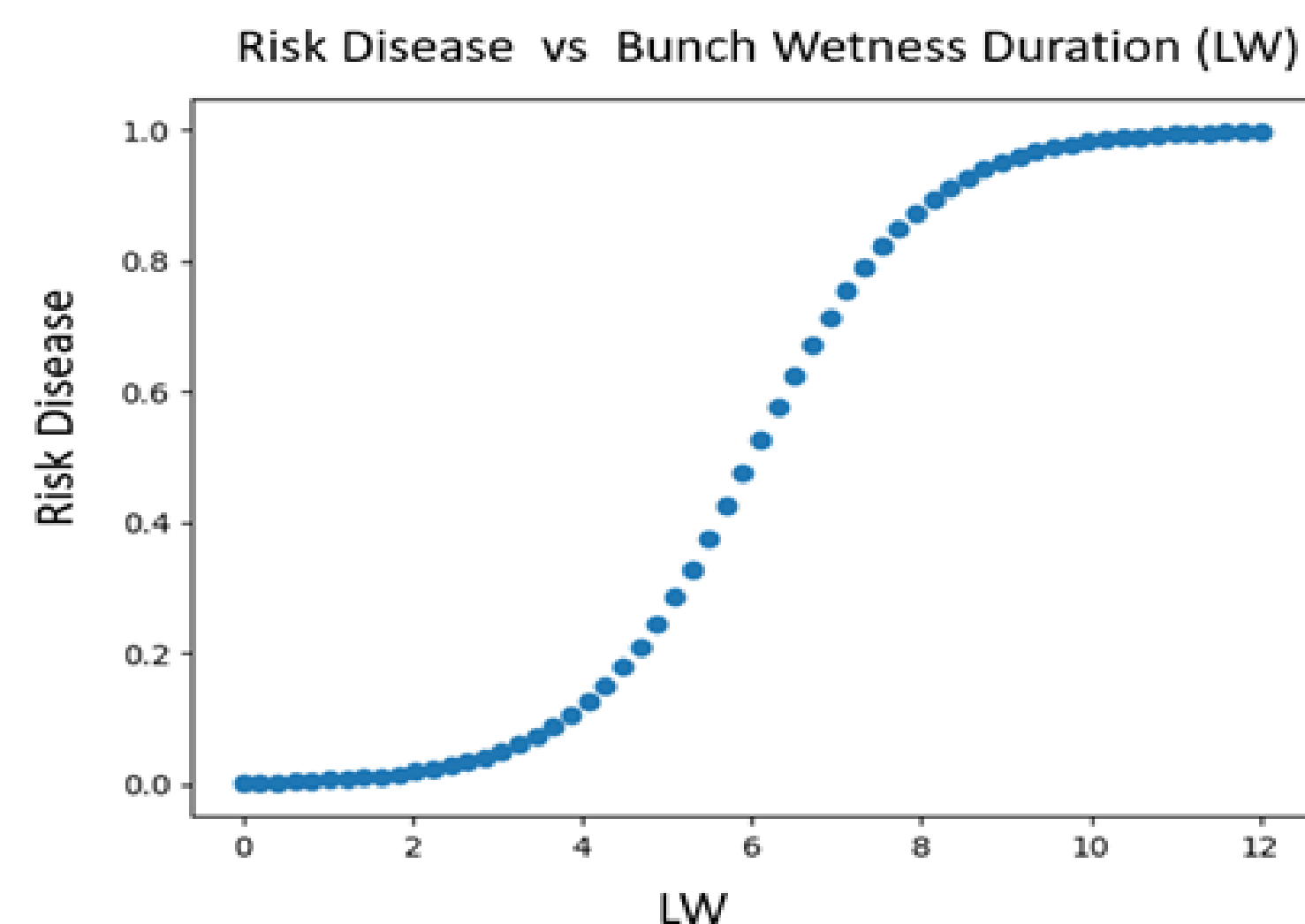


Figure 1. Sigmoidal relationship between bunch wetness duration (LW) and predicted infection risk of *Botrytis cinerea*, with a clear inflection point around 6 h indicating a critical threshold for disease development.

Table 1. Multiple linear regression analysis revealed that all predictors significantly influenced disease risk (p < 0.05).

model	Unstandardized B	Coefficients Std.Error	Standardize Coefficients Beta	t	Sig.	Collinearity Statistics VIF
constant	0.044	0.015		3.016	0.004	
Fludioxynil + Cyprodinil	0.273	0.038	0.345	7.146	0.000	1.605
<i>Bacillus amyloliquefaciens</i>	0.083	0.041	0.135	2.019	0.048	3.103
Infection-Control (untreated)	0.361	0.035	0.626	10.400	0.000	2.498

The untreated control exhibited the strongest effect on disease development ($\beta = 0.626$, $p < 0.001$), indicating that the absence of fungicide treatment was associated with a substantial increase in *Botrytis cinerea* infection risk (table 1). Among the fungicide treatments, Fludioxynil + Cyprodinil showed a significant positive association with disease risk ($\beta = 0.345$, $p < 0.001$), suggesting a moderate influence under the studied conditions. In contrast, *Bacillus amyloliquefaciens* demonstrated a weaker but still statistically significant effect ($\beta = 0.135$, $p = 0.048$). The confidence intervals for all predictors did not cross zero, confirming the robustness of the estimated effects. Additionally, collinearity diagnostics indicated no severe multicollinearity issues ($VIF < 3.5$), supporting the reliability of the model.

Conclusions

The results highlight that environmental conditions, particularly bunch wetness duration, play a dominant role in disease development. While fungicide treatments significantly reduce infection risk, their effectiveness is limited under high disease pressure. This interaction suggests that chemical and biological control measures cannot fully compensate for favorable environmental conditions, emphasizing the need for integrated disease management strategies. Bunch wetness duration is the dominant environmental factor controlling *Botrytis cinerea* infection, while fungicide treatments provide partial but condition-dependent protection. Under prolonged wetness conditions, disease development is primarily driven by environmental factors, limiting the effectiveness of control measures.

$$\text{Risk Disease} = \frac{1}{1 + e^{-(-4.2 + 0.48 \times LW)}}$$