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# High-Throughput phenotyping for leaf-to-fruit ratio characterization in grapevine and its impact on sugar accumulation



PhD (24/01/2024 → 23/01/2027)

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## Context and objective

Controlling sugar levels in grapes is a major challenge for adapting grapevine cultivation to climate change. Sugar levels, which vary widely between varieties, are influenced by factors such as the onset of ripening and the leaf-to-fruit ratio. While operational methods for leaf area quantification already exist, they are limited by their low throughput. The aim of this project is to develop high-throughput methods to characterize grapevine foliage and photosynthetic capacity, enabling an objective analysis of the "sugar accumulation" trait. To achieve this, we utilize phenotyping tools under natural conditions, including LiDAR sensors and high-resolution RGB cameras.

## Methods

### Data Acquisition

#### Ripening monitoring

- ✓ We monitored the following genotypes weekly: Riesling, Gewurztraminer, Chardonnay, and Artaban
- ✓ For Gewurztraminer, three treatments were applied: Leaf Removal (LR), Cluster Removal (CR), and Control (C) on three microplots of five plants per treatment.



Figure 1 : Before and after leaf removal

#### Regular data acquisition with PhenoVine



Figure 2 : The PhenoVine device in Colmar

### Automated image processing chain

- ✓ Algorithms implemented in Python
- ✓ Image preprocessing (white balance, distortion, and vignetting correction)
- ✓ Extraction of the foreground using Midas<sup>1</sup>, a depth estimation model
- ✓ Estimation of exposed leaf area (ELA<sup>2,3</sup>) in square meters per plant
- ✓ Calculation of leaf-to-fruit ratio in square centimeters per berry

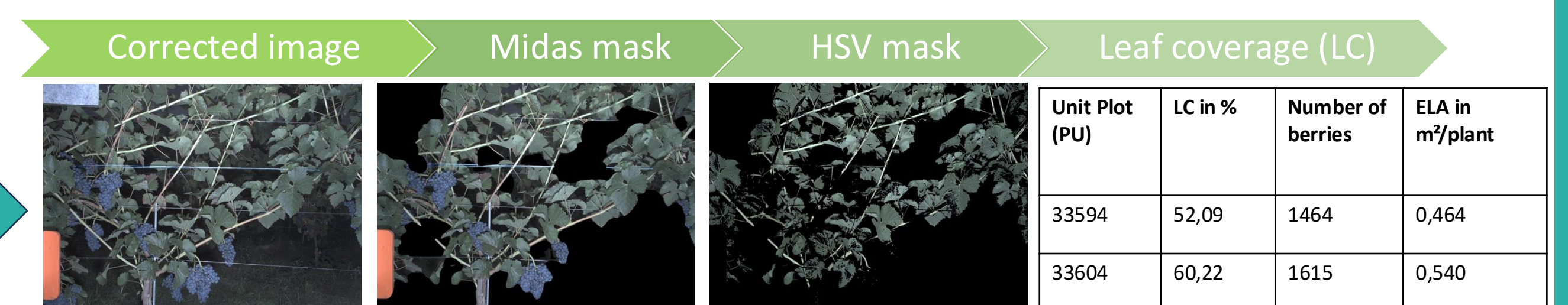


Figure 3 : Steps of image processing

### Automated LiDAR processing chain

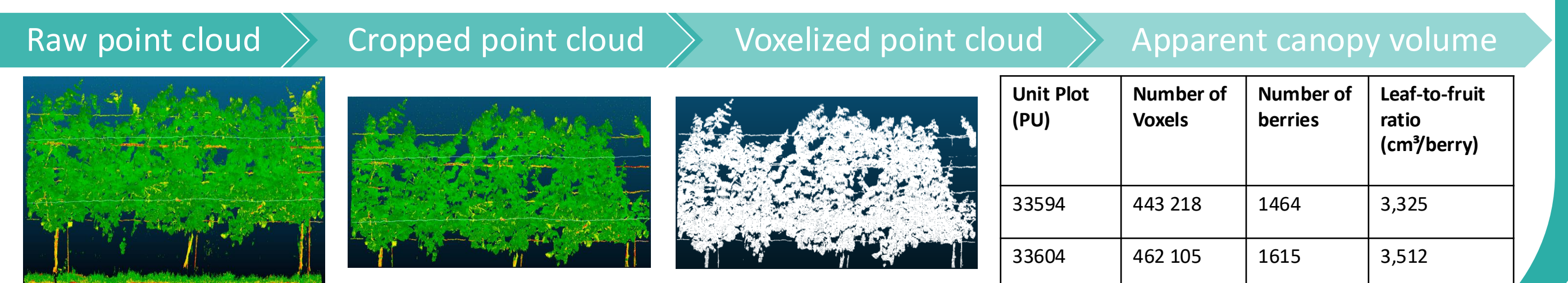


Figure 4 : Steps of LiDAR processing

## Results

### Sugar accumulation monitoring

- ✓ The slopes of the lines represent the rates of sugar accumulation
- ✓ Riesling accumulates sugars the fastest, while Artaban is the slowest.

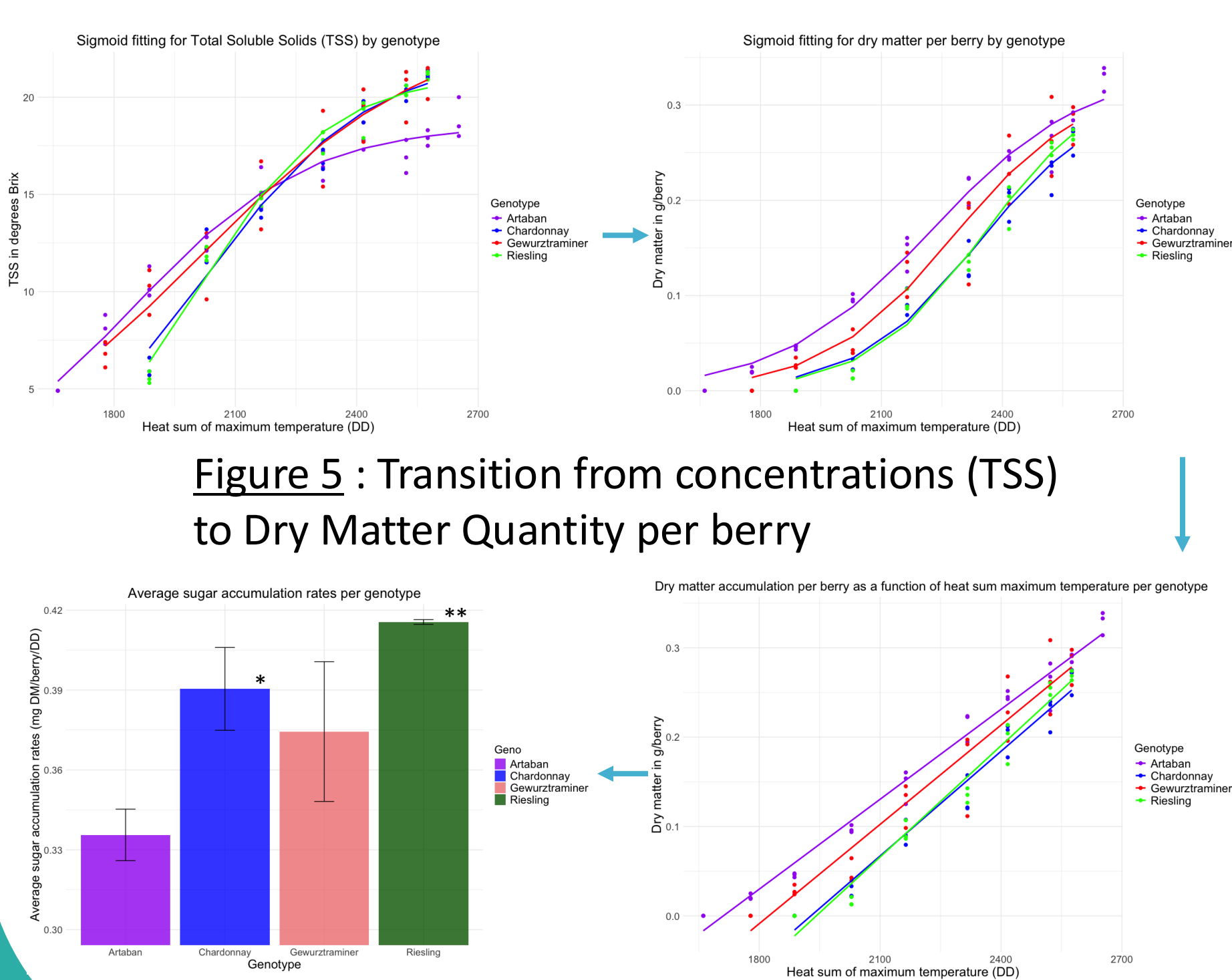


Figure 6 : Sugar accumulation rates

### Leaf-to-fruit estimation

- ✓ Riesling exhibits the highest leaf-to-fruit ratio from RGB and LiDAR data, while Artaban shows the lowest
- ✓ The correlation between RGB and LiDAR data is stronger with sensors observing the upper part of the canopy

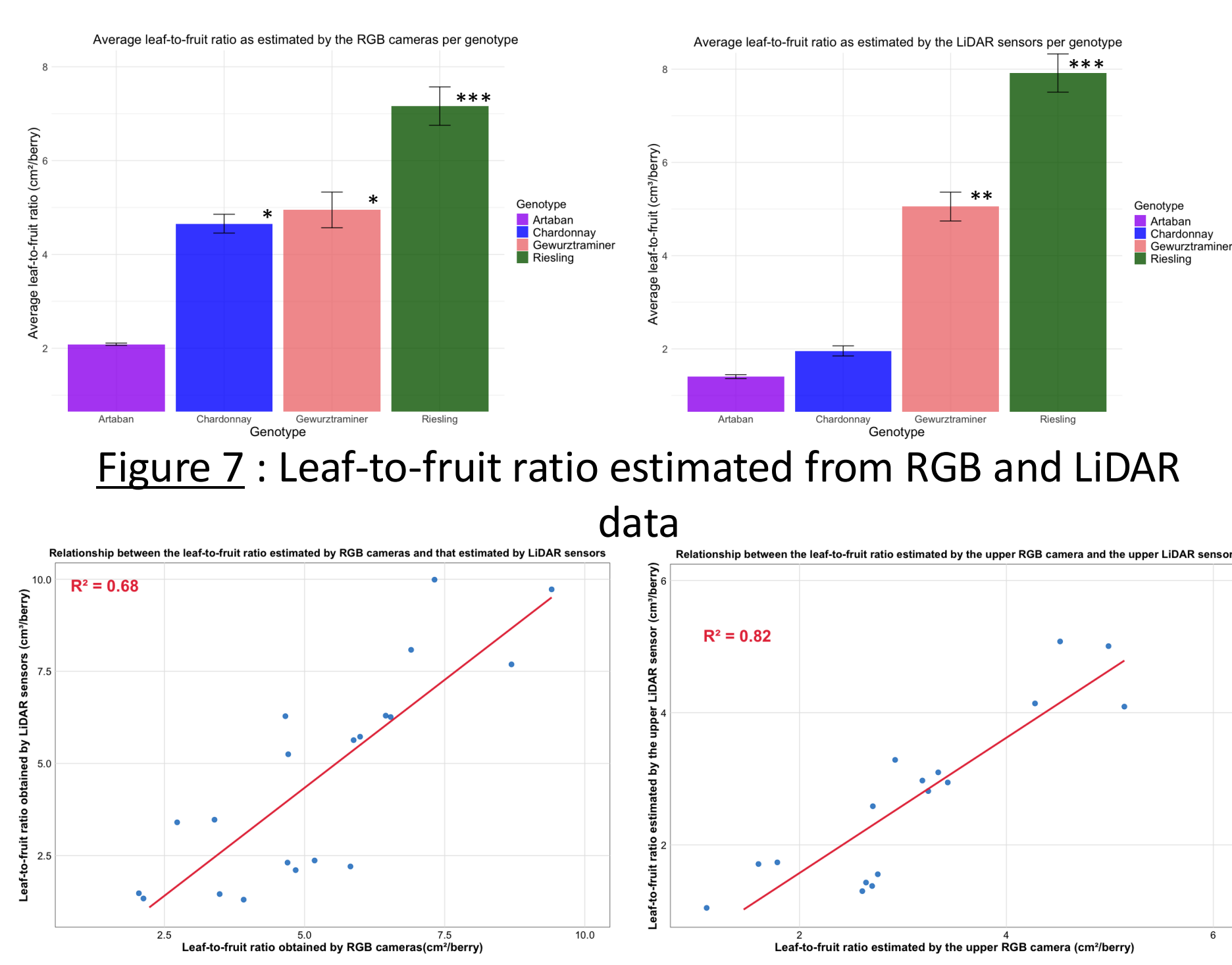


Figure 8 : Relationships between RGB and LiDAR data

### Relationship between leaf-to-fruit and sugar accumulation

- ✓ The relationship is more significant with imaging data than with LiDAR data
- ✓ This relationship is particularly strong for the three treatment modalities of Gewurztraminer

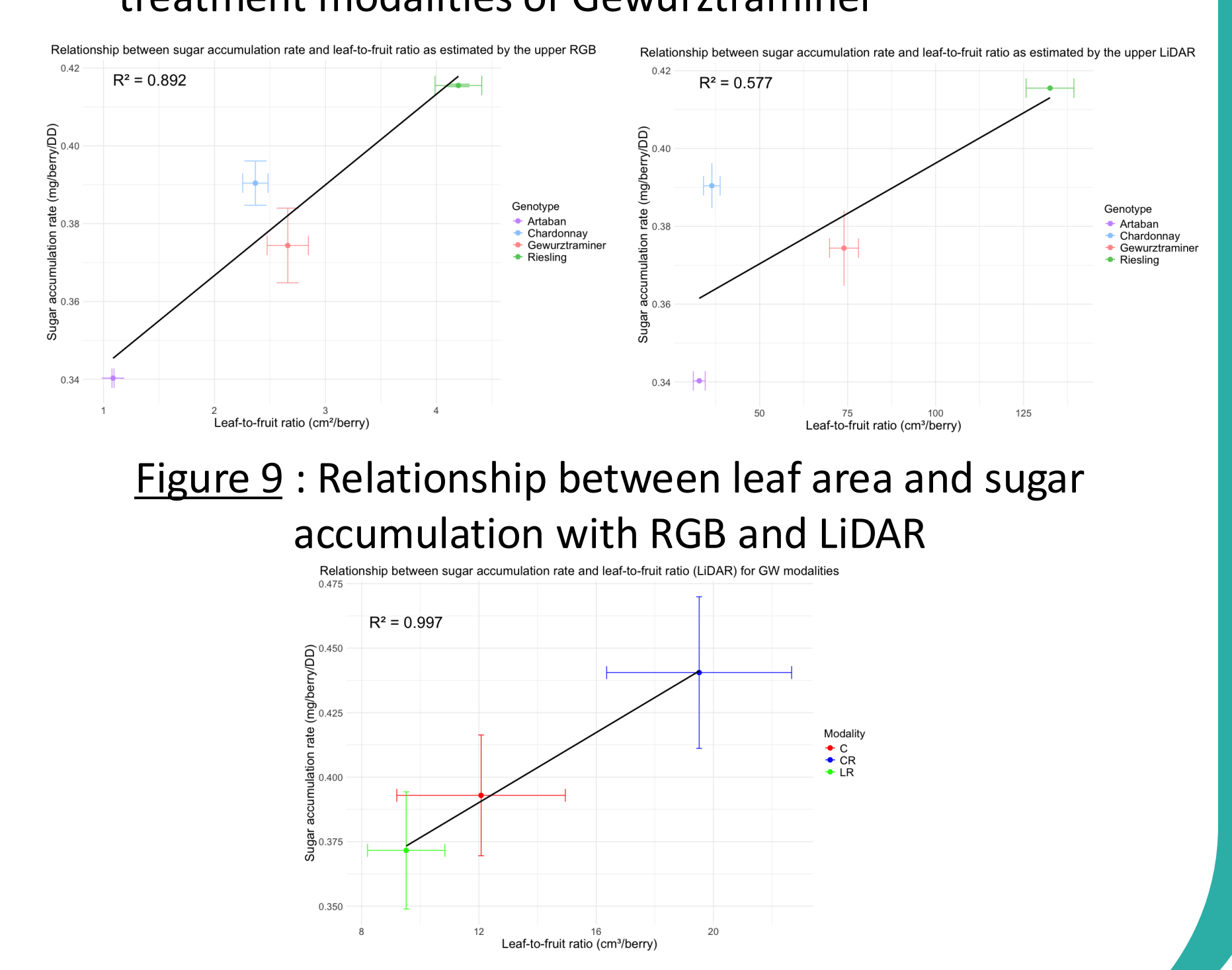


Figure 10 : For Gewurztraminer treatment modalities

## Conclusions and perspectives

### Conclusions

- ✓ A significant relationship has been established between leaf-to-fruit ratio and sugar accumulation rate in the berries
- ✓ Estimation of leaf-to-fruit ratio is more accurate with RGB imaging than LiDAR with the current data processing

### Perspectives

- ✓ Improvement of leaf segmentation in RGB images and optimization of LiDAR data processing
- ✓ Integration of additional genotypes and additional photosynthesis indicators (multispectral indices, Konica-Minolta SPAD502, and LiCOR600)
- ✓ Study of the kinetics of canopy development

<sup>1</sup>Ranftl, R., Lasinger, K., Hafner, D., Schindler, K. et Koltun, V. (2020, 25 August). Towards Robust Monocular Depth Estimation: Mixing Datasets for Zero-shot Cross-dataset Transfer. arXiv

<sup>2</sup>Chedid, E., Avia, K., Dumas, V., Ley, L., Reibel, N., Butterlin, G., Reibel, N., Soma, M., Lopez-Lozano, R., Baret, F., Merdinoglu, D. et Duchene, E. (2023). LiDAR Is Effective in Characterizing Vine Growth and Detecting Associated Genetic Loci. *PLANT PHENOMICS*, 5, 0116.

<sup>3</sup>Carbonneau, A. (1989). L'exposition utile du feuillage: Définition du potentiel du système de conduite. In: Systèmes de conduite de la vigne et mécanisation. Paris: OIVV; 1989. p. 13-33.