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Study Finds 30% Water-Stress Gaps in a Single Stellenbosch Vineyard

Researchers found severe stress raised anthocyanins 23% and tannins 27%, often at the cost of lower yields.

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A multi-year study in South Africa’s Stellenbosch wine region found that vines in the same irrigated Cabernet Sauvignon block can experience sharply different levels of water stress, with direct effects on grape chemistry, wine composition, and yield.

The research, published by WineLand and led by Carlos Poblete-Echeverria, followed vines at Thelema Mountain Vineyards as part of the South Africa Wine program “Grapevine production with limited water resources.” The work examined how differences in water stress across time and space affect vine physiology, fruit composition, and wine quality under commercial growing conditions.

The study was carried out in a 2.24-hectare Cabernet Sauvignon vineyard in the Simonsberg-Stellenbosch area, about 430 meters above sea level. The block was managed as a single unit by the producer, with uniform drip irrigation, but researchers found that water stress was far from uniform. According to the study, spatial variability within the block exceeded 30% over two growing seasons, a level the authors said points to major differences inside a vineyard that appears homogeneous in day-to-day management.

Researchers from the Digital Viticulture Research Group at the South African Grape and Wine Research Institute at Stellenbosch University monitored plant water status weekly from mid-November to harvest. They used midday stem water potential, measured with a pressure chamber, to classify vines into three groups: low stress, moderate stress, and severe stress. The thresholds were set at above −0.9 megapascals for low stress, between −1.2 and −0.9 for moderate stress, and below −1.2 for severe stress.

To capture variability within the block, the team first selected 43 target vines using a combination of soil electrical conductivity mapping, trunk circumference measurements, and vegetation vigor data from Sentinel-2 satellite imagery. After the initial season, those vines were narrowed to 33 that represented the three water-stress classes more clearly.

Each vine was harvested separately, and berry samples were tested for sugar, pH, titratable acidity, and other standard measures. Fruit from individual vines was also vinified separately in small glass fermenters, allowing the team to compare resulting wine phenolics, including anthocyanins and tannins.

The strongest pattern in the data was a trade-off between concentration and production. Vines under severe water stress produced grapes and wines with higher levels of compounds linked to color and structure, but they also yielded less fruit. The

study reported that anthocyanin levels in the severe-stress group were significantly higher than in the low- and moderate-stress groups, with half the observations above 711.1 milligrams per liter. Tannins followed the same direction. In the severe-stress class, 50% of plants exceeded 1,427.7 milligrams per liter, and the mean concentration reached 1,911.2 milligrams per liter.

Sugar concentration also rose under severe stress. In that group, berries fell within a relatively narrow range of 23.7 to 26.5°Brix, which the study said indicated low variability within the class despite the higher stress level. By contrast, malic acid did not differ significantly among the three classes, making it one of the few measured traits that stayed relatively stable.

Yield moved in the opposite direction. The researchers found that half of the vines in the severe-stress class produced less than 3.56 kilograms per vine. In the low- and moderate-stress classes, more than 75% of vines produced over 4.26 kilograms per plant. Across the experiment, tannin levels increased by 27% and anthocyanin levels by 23% when comparing the lower-stress classes with the severely stressed vines. Wines from low-stress vines showed 24% lower total phenolic content than wines from the more stressed vines.

Those results matter because growers are trying to manage vineyards through warmer summers, lower in-season rainfall, and rising evaporative demand in the Western Cape. The study notes that these conditions are already putting more pressure on irrigation in premium wine areas such as Stellenbosch and Paarl, and that climate projections point to continued drying in key regions. Researchers said periods around veraison, when berries soften and begin to color while sugar accumulation speeds up, are especially sensitive because atmospheric demand often peaks at that stage.

The findings suggest that applying the same amount of water across an entire block may miss important differences in how vines actually respond. Even when irrigation infrastructure and schedules are uniform, local variation in soil and plant conditions can produce very different stress patterns and, in turn, different harvest outcomes.

For the beverage sector, the implications extend beyond vineyard management. Wine producers depend on balancing fruit quality with stable production, and the study suggests that more precise irrigation by zone could help conserve water while reducing the risk of unnecessary yield losses. In practice, that could support growers and wineries trying to meet style goals for red wines without pushing too far into severe stress that cuts output. The potential value is especially clear in regions where water supplies are tight and grape supply consistency affects production planning.

The researchers said their results support aiming for controlled, moderate water stress rather than either low stress or severe deficit. In their view, moderate stress offered the best balance between improved berry composition and preserving yield. The study also argued that water-status monitoring should be systematic rather than based mainly on visual assessment or grower experience.

At the same time, the authors noted that stem water potential, while considered a robust physiological indicator, is labor-intensive and difficult to scale across large commercial vineyards. That limitation has led the research group to test other tools, including thermography, sensors, and remote sensing systems that can detect water-stress gradients with higher spatial and temporal resolution.

The work was funded by the South Africa Wine Water Programme under the project “Grapevine production with limited water resources.” Thelema Mountain Vineyards provided logistical support, and the study also involved contributions from researchers and technical staff linked to Stellenbosch University’s digital viticulture program.

The study adds local evidence to a broader body of international research showing that vine water status is a major driver of grape ripening and wine composition. Its main contribution is to show, under commercial conditions in Stellenbosch, how large that variation can be inside a single irrigated block and how strongly it can affect both crop volume and wine-related traits.