

Building Sustainable Vineyards: The Role of Rootstocks, Scions, on Site Adaptation

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Vineyard management has always been an intricate balance of selecting the right tools to harmonize with the environment. Among these tools, rootstock and scion selection play pivotal roles in shaping grapevine performance and fruit quality. Understanding how these elements interact with site-specific conditions and climate is more critical than ever in the context of evolving climatic challenges such as increased seasonal variability and extremes of precipitation and drought.

The Role of Rootstocks

Rootstocks are often the unsung heroes of viticulture. Initially introduced to combat phylloxera, rootstocks are now integral to managing a wide range of abiotic stresses such as drought, salinity, and extreme temperatures. Rootstocks influence water and nutrient uptake, canopy vigor, and even phenological timing, making them essential in maintaining vine productivity.

For example, rootstocks derived from *Vitis berlandieri* are particularly well-suited for calcareous soils, while those with *Vitis riparia* ancestry excel in regions with ample water but may falter under drought conditions (Galet, 1979; Keller et al., 2008). Studies like those of Rahemi et al. (2022) have repeatedly shown that rootstock selection tailored to specific environmental conditions improves vineyard resilience.

Scion Clone Selection

While rootstocks provide the foundation, scion clones determine the vineyard's "personality," defining the variety of the harvested crop, shaping fruit quality, yield, berry cluster architecture, and canopy structure. While performance differences among varieties can be huge, clonal differences within a variety, in general, may be less pronounced but potentially offer some important climatic adaptation which should not be overlooked in plant selection, particularly for regions where market conditions reward the production of a specific variety. Clones can play a role in modulating the canopy's stress responses, influencing both vigor and resilience under varying environmental conditions. For example, Cabernet Sauvignon Clone 8 (CS8) demonstrated notable resilience in a recent study conducted at the UC Davis Oakville Station in Napa County, where it outperformed other clones in the trial. This study demonstrated significant differences in how scion clones modulate canopy stress, yield stability, and fruit composition over the 2022, 2023, and 2024 seasons. Clone CS8 consistently exhibited greater resilience to environmental stresses compared to Cabernet Sauvignon Clone 15 (CS15) and Cabernet Sauvignon Clone 65 (CS65), maintaining higher yield stability and desirable fruit quality metrics under variable climatic conditions. CS15 showed more stress in terms of NDVI values, chlorophyll content, and canopy temperatures, while CS65 tended to produce smaller canopy than CS15 but maintained higher NDVI values. These findings emphasize the potential role of scion selection in addressing site-specific challenges and adapting to evolving climate patterns. Research has shown that scion clones influence traits like sugar accumulation, acidity, and phenolics, all of which are critical to wine quality (Keller, 2020).

The Site Effect

Site-specific factors, including soil composition, water availability, and microclimate profoundly influence the performance of rootstock and scion. Rootstocks like 1103 Paulsen, known for their deep rooting ability, thrive in arid regions by accessing subsurface water, while shallower-rooting options like *Vitis riparia* hybrids excel in well-watered soils. Studies indicate that aligning rootstock and scion characteristics with site conditions can optimize productivity and minimize stress (Fichtl et al., 2023).

The Climate Connection

Climate acts as both a backdrop and a dynamic force in vineyard management. Acute stress events like heatwaves and droughts accompany long-term trends such as rising temperatures and changing precipitation patterns. These factors underscore the importance of adaptability in rootstock-scion combinations. For example, Edwards et al. (2022) documented how rootstocks confer traits that can alter the crop water use index of the scion in a mature vineyard and accurately matching available water resources with conferred vigor and leaf physiology traits of the chosen rootstock has the potential to be used as a tool to optimize vineyard water use efficiency.

Synthesis of Research Insights

The Oakville Rootstock Trial in Napa Valley provides a contemporary example of how these elements converge. This trial evaluated four rootstocks (5BB, 110R, 420A, and 3309C) and three scion clones (CS8, CS15, and CS65) under moderate deficit irrigation (60%ET_c) conditions. Drone imagery collected during the 2024 harvest highlighted significant differences among rootstocks and clones in canopy surface area, vegetation indices such as NDVI, and canopy temperature. For example, 5BB supported the largest canopy surface area (0.82 m²) and highest NDVI values, while CS8 maintained the most balanced canopy temperatures, indicating superior stress resilience. These metrics align with the trial's broader findings, showing that 5BB and CS8 consistently performed well in yield stability and fruit composition across variable climatic conditions. Over three seasons, researchers evaluated four rootstocks and three scion clones under moderate deficit irrigation. Rootstock 5BB and Clone CS8 emerged as top performers, supporting vigorous canopies and stable yields even under drought conditions. These findings also demonstrate the value of integrating advanced monitoring tools, such as drone imagery, with traditional yield measurements to better understand how rootstock and clone selection can optimize vineyard performance. Matching plant material to both site and climate is key to sustaining productivity and quality in the face of climate variability.

Practical Considerations for Growers

Selecting the appropriate rootstock for a vineyard provides long-term adaptation benefits. It is a nuanced decision that requires a deep understanding of the challenges presented by a specific site. Soil type, water availability, and climate are all key factors influencing rootstock performance. Testing for nematodes is especially crucial when replanting a vineyard following the removal of established vines, as older vines are often more tolerant to nematodes compared to newly planted

ones, and nematode populations can build up over time. This testing helps determine whether nematode-resistant rootstocks are necessary to address potential infestations that could threaten young vines. Rotating rootstocks with different genetic parentages serves a similar purpose to crop rotation in annual agriculture: it disrupts the life cycles of soil pests and discourages their adaptation to feeding on grapevine roots. This practice helps prevent the evolution of pest populations that specialize in specific rootstock lineages, ensuring the long-term health and productivity of the vineyard.

Scion selection complements this process by ensuring that the chosen clone aligns with production goals and is resilient under the expected climatic conditions. Growers must think long-term, taking into account both current challenges and future trends to ensure sustainable vineyard performance. By carefully assessing site-specific factors and adapting management practices, vineyards can remain resilient and productive amid evolving climatic conditions.

Adapting for a Sustainable Future

As viticulture navigates the complexities of climate change, the strategic use of rootstocks and scions will remain central to vineyard success. By combining site-specific insights with advancements in technology and breeding, growers can enhance resilience, optimize resource use, and sustain grape quality for future generations.

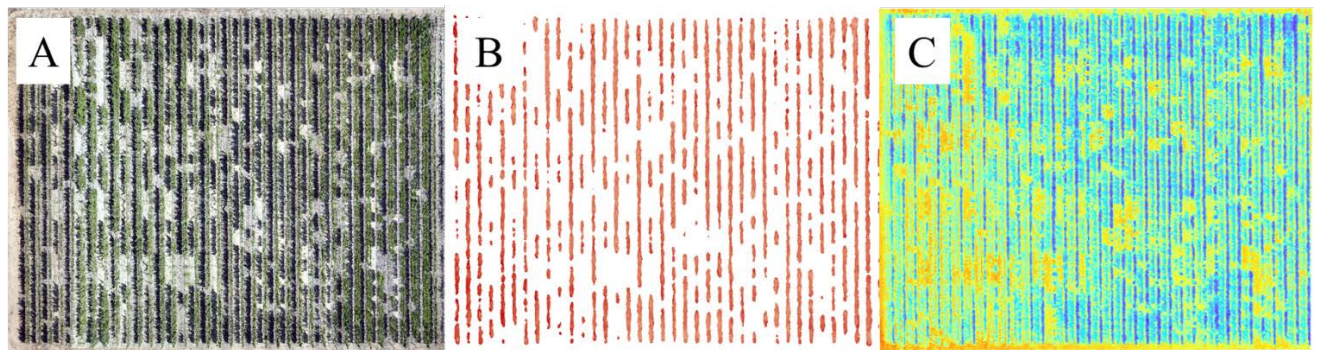


Figure 1. Drone imagery of the Oakville Rootstock x Clone trial showing A) standard color imagery, B) digital canopy model used to estimate canopy size, and C) NDVI used to estimate vine vigor.

Table 1. Canopy characteristics and temperature metrics for four rootstocks (5BB, 110R, 3309C, and 420A) and three scion clones (CS8, CS65, and CS15) measured on October 5, 2024. Metrics include canopy surface area (m^2), vegetation indices (NDVI, GNDVI, NDRE), and canopy temperatures (mean and maximum). Statistical significance was determined using two-way ANOVA followed by Duncan's Multiple Range post-hoc test. Significant differences ($p < 0.05$) are denoted by different letters within rootstock and clone groups, highlighting the effects of rootstock and

clone on canopy stress and vigor. Rootstock x Clone interactions were not significant for these parameters.

	Canopy surface area (m ²)	Mean NDVI	Mean GNDVI	Mean NDRE	Canopy Surface Temp Mean (C)	Canopy Surface Temp Max (C)
10/5/2024						
Rootstock						
5BB	0.82 a	0.6934 a	0.6764 a	0.3021 a	43.27 c	50.97
110R	0.78 ab	0.6877 a	0.6770 a	0.2961 a	43.50 ab	51.11
3309C	0.72 b	0.6709 b	0.6623 b	0.2859 b	43.28 b	50.98
420A	0.60 c	0.6859 a	0.6710 a	0.3015 a	43.79 a	50.88
<i>p value</i>	<0.0001	0.0005	0.0011	0.0003	0.0095	0.9414
Clone						
CS8	0.77 a	0.6941 a	0.6768 a	0.2991 a	43.32 b	50.76 b
CS65	0.68 b	0.6892 a	0.6760 a	0.3001 a	43.39 b	50.27 b
CS15	0.75 a	0.6680 b	0.6609 b	0.2886 b	43.69 a	52.07 a
<i>p value</i>	0.0064	<0.0001	<0.0001	0.0040	0.039	<0.0001
Rootstock x Clone						
<i>p value</i>	0.8286	0.2204	0.6809	0.8170	0.2294	0.1831

Table 2. Yield components for four rootstocks (5BB, 110R, 420A, and 3309C) and three scion clones (CS8, CS15, and CS65) across the 2022, 2023 and 2024 growing seasons. Metrics include yield (kg/vine), cluster number per vine, and average cluster weight (g). Statistical significance was determined using two-way ANOVA followed by Duncan's Multiple Range post-hoc test. Significant differences ($p < 0.05$) are denoted by different letters within rootstock and clone groups, highlighting the effects of rootstock and clone on production metrics. Rootstock x Clone interactions were not significant for these parameters.

	Yield (kg/vine)		Cluster number	Cluster weight (g)	
Rootstock					
110R	3.82	ab	40.00	91	a
420A	3.87	ab	42.68	89	ab
5BB	4.22	a	42.14	100	a
3309C	3.22	b	41.32	76	b
<i>p value</i>	0.0453		0.7755	0.0013	

Clone			
CS8	4.43 a	40.41 b	107.94 a
CS15	3.07 b	38.00 b	77.29 b
CS65	3.97 a	46.51 a	84.08 b
<i>p value</i>	<.0001	0.0004	<.0001
Rootstock x Clone			
<i>p value</i>	0.1941	0.3258	0.0638

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