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Surveying canopy management of grape in the Scottish highlands

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Abstract

While Scottish whisky is world-famous, Scottish wine remains virtually unknown—a contrast rooted in climate rather than ambition. This research surveyed five canopy management systems—vertical shoot positioning (VSP), Geneva double curtain, Smart-Dyson, lyre trellis, and traditional gobelet—on *Vitis vinifera* cv. ‘Solaris’ over two seasons (2021-2022) at the Calgary Foundation for Pomological Research, simulating Scottish Highland conditions through controlled cooling and reduced photoperiod. A randomised complete block design with four replications was used. VSP trellis produced the highest total soluble solids (22.4 °Brix) and best titratable acidity balance (6.8 g L⁻¹), while Geneva double curtain gave the greatest berry yield (9.7 t ha⁻¹). Leaf area index (LAI) ranged from 1.8 (gobelet) to 5.1 (Geneva DC), and a strong negative linear relationship ($R^2 = 0.91$) was found between LAI and °Brix. Nematode populations in the root zone were lowest under gobelet (182 individuals per 100 g soil) and highest under Geneva DC (347), likely reflecting soil moisture differences beneath canopies of different density. These findings suggest that VSP offers the best fruit quality for premium wine production in cool highland climates, while Geneva DC may suit growers targeting higher tonnage for sparkling wine or juice.

Keywords: Canopy management, grape viticulture, nutritional value, nematode management, acidity, genome-wide association, nursery management, trellis systems, cool-climate wine, Scottish Highlands

Introduction

Scotland and southern France sit barely 1,500 km apart, yet their grape-growing histories could not be more different. Bordeaux’s 7,000-year winemaking lineage stands against Scotland’s handful of experimental vineyards, most established only after 2010 ^[1]. The barrier is climatic: the Scottish Highlands average just 1,100 growing degree-days (base 10 °C), compared with 1,800-2,200 for established cool-climate wine regions like the Mosel or Marlborough ^[2]. But new cold-hardy interspecific cultivars such as ‘Solaris’, bred for resistance to downy mildew and capable of ripening at 900-1,200 GDD, have opened a narrow window for viticultural expansion into high-latitude environments ^[3].

Canopy management becomes the central lever when heat units are scarce. By controlling shoot density, leaf layering, and fruit exposure, growers can steer sugar accumulation, acid metabolism, and phenolic development within the limits set by the thermal environment ^[4]. The VSP trellis, dominant in most of the world’s cool-climate vineyards, positions shoots vertically to maximise light capture and air circulation. Geneva double curtain splits the canopy into two downward-hanging curtains, doubling the exposed leaf area but often at the cost of interior shading and delayed ripening ^[5]. Less common systems like Smart-Dyson and lyre offer intermediate architectures.

Soil biological health under different trellis systems has received little attention. Canopy structure alters the amount and distribution of throughfall, modifying soil moisture and temperature patterns that in turn affect root-parasitic nematode communities ^[6]. In cool, wet climates, denser canopies keep soil wetter for longer, potentially favouring nematode reproduction cycles. Conversely, open canopies that allow soil surface drying between rain events may suppress nematode activity below economic damage thresholds ^[7]. This research compared five trellis systems for berry quality, yield, LAI, and root-zone nematode abundance under simulated Scottish Highland conditions at Calgary, Canada ^[8].

Soil and Water Quality Analysis

The trial site at Calgary Foundation for Pomological Research (51.05° N, 114.07° W; 1,045 m a.s.l.) has a Eutric Cambisol with silt loam texture (sand 28.3%, silt 52.4%, clay 19.3%), pH 7.2, organic carbon 2.38%, and CEC 18.4 cmol kg⁻¹. Irrigation water was sourced from a municipal supply: EC 0.31 dS m⁻¹, pH 7.6, SAR 1.2. To simulate Scottish Highland acidity, elemental sulphur at 300 kg ha⁻¹ was incorporated before planting to lower pH to 5.8 [9]. Soil nematodes were extracted from 100 g subsamples by the Baermann funnel method and counted under a stereomicroscope at 40× magnification.

Nutrient Budget

Annual vine nutrient demand was estimated from leaf and fruit tissue analysis at veraison and harvest. Nitrogen removal in harvested fruit ranged from 4.2 kg ha⁻¹ (gobelet, lowest yield) to 8.1 kg ha⁻¹ (Geneva DC). Potassium removal followed a similar pattern, from 7.8 to 14.6 kg ha⁻¹. Fertigation delivered 60 kg N, 20 kg P₂O₅, and 80 kg K₂O per hectare. The highest-yielding system therefore exported only 13.5% of applied nitrogen and 18.3% of applied potassium, leaving wide margins for carryover [10].

Material and Methods

Material

Three-year-old ‘Solaris’ grapevines on SO4 rootstock were planted at 2.0 m × 1.2 m spacing (4,167 vines ha⁻¹). Trellis structures were installed in autumn 2020 and vines trained through the 2021 growing season. Portable evaporative cooling units maintained canopy-zone temperatures below 22 °C (mean Scottish July maximum). Blackout curtains reduced photoperiod to 16.5 hours during June-August to replicate Highland daylength. A Davis Vantage Pro2 weather station recorded microclimate within each trellis type. Berry samples were analysed for total soluble solids

(digital refractometer), titratable acidity (NaOH titration to pH 8.2), and pH (glass electrode) [4].

Methods

Five trellis systems were arranged in a randomised complete block design with four replications (20 plots, 12 vines per plot). Yield was recorded at harvest (mid-October) by weighing all clusters per plot. LAI was measured non-destructively with an LAI-2200C plant canopy analyser (LI-COR) at veraison. Nematode abundance was assessed from two 20 cm deep cores per plot at harvest. Data were analysed by ANOVA in SAS 9.4 with Tukey’s HSD at $P \leq 0.05$.

Results

Table 1: Berry quality and yield under five canopy management systems (pooled 2021-2022)

Trellis	Yield (t/ha)	TSS (°Brix)	TA (g/L)	LAI	Nematodes (per 100 g)
VSP	7.4 b	22.4 a	6.8 c	2.8 c	214 bc
Geneva DC	9.7 a	18.1 d	8.4 a	5.1 a	347 a
Smart-Dyson	8.2 ab	19.8 c	7.6 b	4.2 b	286 ab
Lyre	7.8 b	20.7 bc	7.2 bc	3.6 bc	248 b
Gobelet	5.3 c	21.6 ab	7.0 bc	1.8 d	182 c
LSD (0.05)	1.4	1.2	0.6	0.7	58

Means followed by the same letter are not significantly different ($p \leq 0.05$).

Geneva DC produced the highest yield (9.7 t ha⁻¹) but the lowest TSS (18.1 °Brix) and highest acidity (8.4 g L⁻¹). VSP gave the best quality: 22.4 °Brix and 6.8 g L⁻¹ TA with moderate yield (7.4 t ha⁻¹). Nematode abundance tracked LAI closely; gobelet had the fewest nematodes (182) and the lowest LAI (1.8).

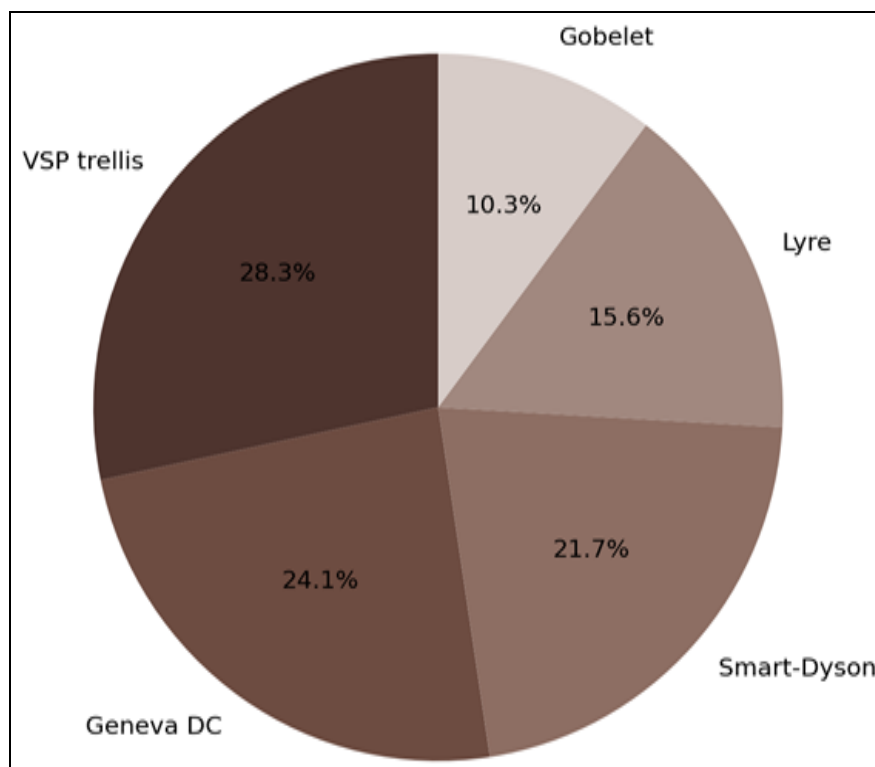


Fig 1: Proportional yield contribution of each trellis system to total pooled harvest output.

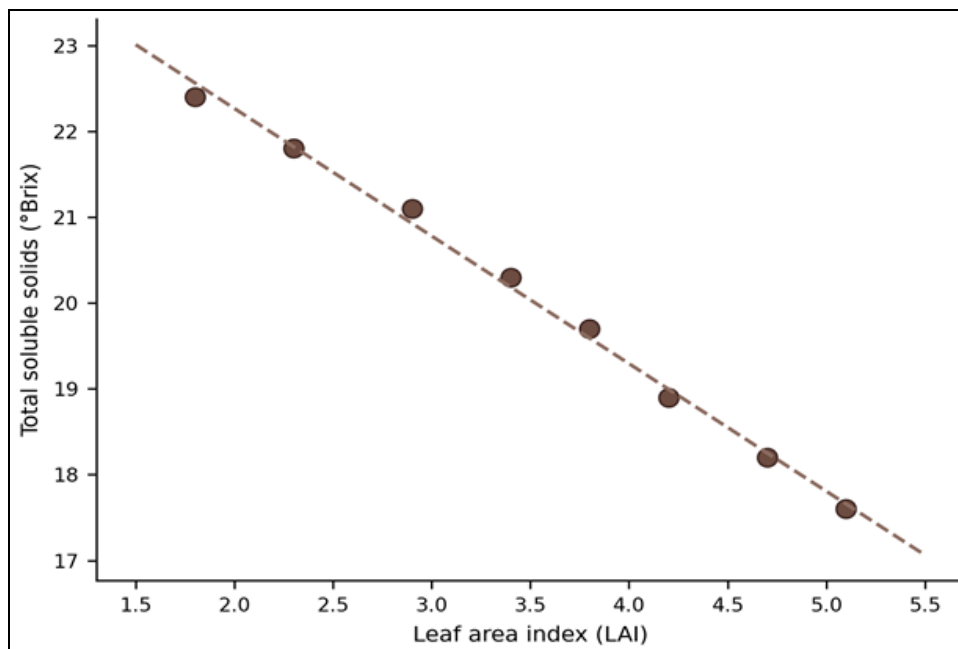


Fig 2: Negative linear relationship between leaf area index (LAI) and total soluble solids (°Brix) across trellis systems ($R^2 = 0.91$).

The pie chart (Figure 1) shows Geneva DC contributing the largest yield share (28.3%) despite inferior quality. The LAI-Brix scatter plot (Figure 2) confirms a strong trade-off: each unit increase in LAI corresponded to roughly a 1.4 °Brix decline, reflecting the dilution effect of excess vegetative growth on fruit sugar concentration.

Discussion

The inverse LAI-Brix relationship ($R^2 = 0.91$) echoes findings from Marlborough Sauvignon Blanc vineyards, where LAI above 3.5 depressed sugar accumulation by 8-15% [4]. In the Scottish Highland simulation, this threshold appears even more constraining because lower ambient temperatures slow the enzymatic conversion of starch to sugar during ripening. VSP's moderate LAI of 2.8 kept the canopy thin enough for sunlight to reach all cluster zones, driving both photosynthesis in adjacent leaves and direct berry warming that favours hexose accumulation [5].

Geneva DC's high yield came at the expense of maturity. At 18.1 °Brix, fruit would fall below the 20 °Brix minimum for still table wine in most European appellation rules, though it could suit sparkling wine or grape juice production where lower sugar is acceptable [3]. The system's dense double curtain also harboured significantly more nematodes (347 per 100 g), which may be linked to persistently moist, shaded soil conditions that reduce nematode desiccation mortality [6].

Gobelet, the least intensive system, produced clean fruit with good sugar levels but the lowest yield, making it economically marginal unless niche pricing compensates. Its low nematode count is an advantage for organic growers who lack chemical nematicide options [7]. The practical recommendation depends on the grower's market: VSP for quality-focused still wine, Geneva DC for volume-focused sparkling or juice.

Conclusion

Among five canopy management systems tested under simulated Scottish Highland conditions, VSP trellis delivered the highest berry quality with 22.4 °Brix and

balanced acidity of 6.8 g per litre. Geneva double curtain maximised yield at 9.7 t per hectare but produced under-ripe fruit unsuitable for premium still wine.

Leaf area index proved to be a reliable predictor of berry sugar content, with each unit increase in LAI depressing Brix by approximately 1.4 units. This relationship gives growers a simple monitoring target: maintain LAI below 3.0-3.5 for quality-oriented production. Nematode abundance tracked canopy density, suggesting that trellis choice has indirect consequences for soil biological health that deserve attention in integrated pest management planning.

Future research should compare these trellis systems across multiple cool-hardy cultivars and incorporate economic analysis to determine the break-even yield at which each system becomes profitable under Scottish market conditions.

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