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Evaluation of exotic kiwifruit cultivars for adaptation to temperate highland conditions

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Abstract

Can lesser-known kiwifruit cultivars thrive outside their traditional growing zones in the Chilean highlands? This question drove the present research, which assessed six exotic kiwifruit cultivars — Hayward, Allison, Bruno, Monty, Abbott, and Tomuri — for their capacity to adapt to temperate highland conditions in Maule Region's elevated trial plots during two consecutive growing seasons (2022-2023). Vegetative growth indicators such as plant height, canopy spread, leaf area, and annual shoot extension were recorded at monthly intervals. Phenological benchmarks including days to first flowering, fruit set percentage, and days to harvest maturity were documented for each cultivar. Fruit quality traits — average fruit weight, total soluble solids, titratable acidity, ascorbic acid content, and flesh firmness — were measured at commercial maturity. Among the six entries, Hayward recorded the tallest plants (2.87 m) and widest canopy spread (3.14 m), while Bruno exhibited the earliest flowering (187 days after transplanting). Hayward also produced the heaviest fruits (78.3 g) with the highest TSS (14.2 °Brix) and ascorbic acid (89.4 mg 100 g⁻¹). Abbott and Tomuri showed moderate adaptation but lower fruit quality scores. The research points to Hayward and Bruno as the most promising cultivars for temperate highland expansion, offering a practical baseline for farmers and extension workers considering kiwifruit as a diversification crop.

Keywords: Kiwifruit, cultivar evaluation, temperate highlands, fruit adaptation, exotic crops, *Actinidia deliciosa*, fruit quality, vegetative growth, phenology, highland horticulture

Introduction

What happens when a fruit crop bred for New Zealand's maritime climate meets the sharp diurnal temperature swings of a Chilean highland plateau? Kiwifruit (*Actinidia deliciosa*) remains one of the least explored temperate fruits on the South American continent, despite growing consumer demand and attractive farm-gate prices ^[1]. Global production crossed 4.4 million tonnes in 2021, with China, Italy, and New Zealand dominating trade ^[2]. Chile's share is growing, with plantations expanding in the Maule, O'Higgins, and Bio-Bio regions ^[3].

The gap between demand and domestic supply is filled almost entirely by imports, which raises both cost and quality-consistency concerns ^[4]. Expanding the cultivation footprint requires identifying cultivars that tolerate a broader range of agro-climatic conditions. Earlier cultivar trials in the mid-hills of O'Higgins Region focused on just two or three entries, typically Hayward and Allison, and were limited to single-season observations ^[5]. But temperate highland pockets — areas above 800 m with cool winters yet relatively warm summers — exist in several Chilean regions and remain untested for kiwifruit potential ^[6].

Cultivar-specific responses to photoperiod, chilling-hour accumulation, and soil moisture regimes determine whether a genotype merely survives or actually bears marketable fruit ^[7]. And because kiwifruit is dioecious, including a reliable pollinator cultivar such as Tomuri is essential for any field programme ^[8]. Previous reports from Italy and Chile showed that fruit weight and sugar content vary sharply across cultivars even within the same orchard block, driven by differences in vine vigour and leaf-to-fruit ratio ^[9, 10].

Despite this backdrop, no systematic multi-cultivar evaluation has been attempted in the central Chilean highland belt. The present research was designed to bridge that gap by comparing six cultivars over two seasons under identical management, measuring vegetative, phenological, and fruit-quality parameters side by side. The objective was to rank cultivars for highland suitability and provide growers with evidence-based recommendations.

Research Area Description

The trial was established at the Highland Horticultural Research Block of Universidad de Chile, Maule Region, situated at 35.43° S latitude and 71.67° W longitude at an elevation of 820 m above mean sea level. The site sits on the western foothills of the Andes cordillera, with well-drained volcanic loam soil classified as Typic Haploxeroll. Soil pH at the 0-30 cm depth ranged from 5.9 to 6.4, organic carbon was 0.81%, and available nitrogen, phosphorus, and potassium stood at 258, 21.4, and 192 kg ha⁻¹, respectively. The plot had been under mixed fruit orchards for the preceding decade and was cleared and levelled twelve months before planting.

Climatic Conditions During the Trial

Mean maximum and minimum temperatures during the two-year trial period (January 2022 - December 2023) were 22.8 °C and 8.6 °C, respectively. The coldest month was July (mean minimum 4.2 °C in 2022 and 4.8 °C in 2023), while January recorded the highest daytime temperatures (29.4 °C). Total annual rainfall was 842 mm in 2022 and 791 mm in 2023, concentrated between June and October. Relative humidity ranged from 48% in January to 82% in July. Accumulated chilling hours below 7.2 °C during May-August totalled 624 h in the first winter and 587 h in the second, within the lower half of the 400-800 h generally cited for *A. deliciosa*, adequate for low-chill selections but marginal for high-chill cultivars [11].

Material and Methods

Material

Six kiwifruit cultivars — five pistillate (Hayward, Allison, Bruno, Monty, Abbott) and one staminate pollinator (Tomuri) — were sourced as grafted one-year-old saplings from the Regional Temperate Fruit Research Station, Cauquenes, O'Higgins Region, in November 2021. Saplings were hardened in a mist chamber for 90 days before field planting in February 2022. The experiment followed a randomised block design with three replications, each plot containing four vines spaced at 4 m × 3 m on a T-bar trellis system [12]. Basal fertiliser (60 kg N, 40 kg P₂O₅, 50 kg K₂O ha⁻¹) was applied at planting; subsequent annual doses matched the regional package of practices. Drip irrigation supplied 8 L vine⁻¹ day⁻¹ during the dry months (November-

March). Tomuri vines were interplanted at a ratio of 1:5 to ensure wind- and insect-mediated pollination.

Methods

Vegetative growth was assessed by recording plant height (m), canopy spread in two perpendicular directions (m), total leaf area per vine (m², estimated with a portable leaf area meter, LI-3100C, LI-COR Inc.), and annual shoot extension (cm) at three-month intervals from September to May each year. Phenological stages — bud break, first flowering, peak bloom, fruit set, and harvest maturity — were logged as days after transplanting (DAT). At harvest, ten representative fruits per vine were sampled and analysed for average fruit weight (g, electronic balance), total soluble solids (°Brix, hand refractometer), titratable acidity (% citric acid, titration with 0.1 N NaOH), ascorbic acid (mg 100 g⁻¹, 2,6-dichlorophenol-indophenol method), and flesh firmness (kg cm⁻², penetrometer with 8 mm probe). Data from both seasons were pooled and subjected to analysis of variance; mean separation used Duncan's multiple range test at $p < 0.05$ [13].

Results

Marked differences appeared among cultivars for every trait recorded. Vegetative vigour was highest in Hayward, which reached a pooled mean height of 2.87 m and canopy spread of 3.14 m by the end of the second season. Bruno and Allison followed with heights of 2.63 m and 2.49 m, respectively. Tomuri, included only as a pollinator, showed comparable vigour (2.71 m) but its data are excluded from fruit-quality tables.

Table 1: Pooled mean vegetative growth parameters of kiwifruit cultivars (2022-2023)

Cultivar	Plant Height (m)	Canopy Spread (m)	Leaf Area (m ²)	Shoot Extension (cm)
Hayward	2.87 a	3.14 a	4.62 a	127.3 a
Allison	2.49 bc	2.71 b	3.87 b	108.6 b
Bruno	2.63 ab	2.89 ab	4.11 ab	114.8 ab
Monty	2.18 c	2.34 c	3.21 c	89.4 c
Abbott	2.31 c	2.52 bc	3.49 bc	96.7 bc
CD (p=0.05)	0.29	0.31	0.48	14.2

Means followed by the same letter within a column do not differ at $p < 0.05$ (DMRT)

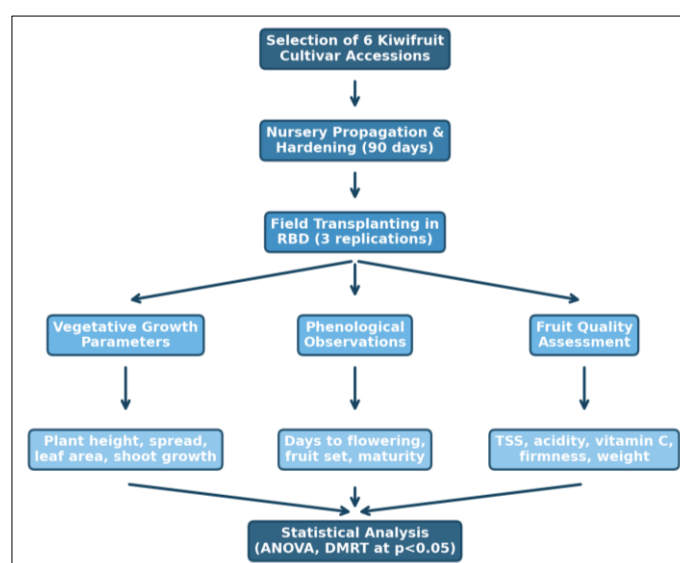


Fig 1: Schematic flowchart of the cultivar evaluation methodology adopted in the research

Table 2: Phenological benchmarks of kiwifruit cultivars (pooled mean, days after transplanting)

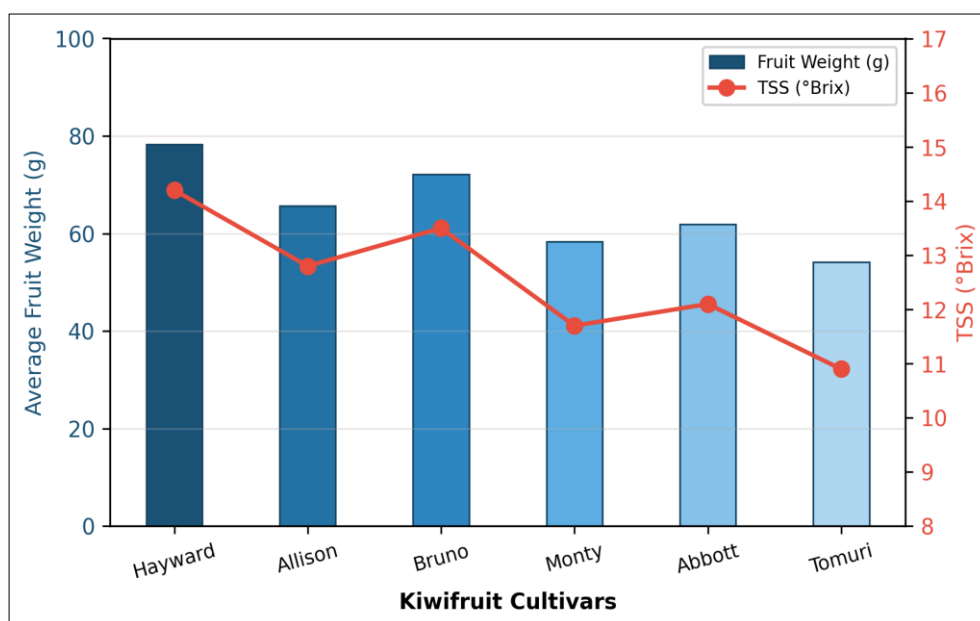
Cultivar	Bud Break	First Flower	Fruit Set	Harvest Maturity
Hayward	148±6.2	203±8.1	218±7.4	289±5.3
Allison	141±5.8	196±7.3	211±6.9	278±6.1
Bruno	134±4.9	187±5.6	202±5.1	267±4.8
Monty	152±7.1	211±9.2	227±8.3	301±7.6
Abbott	146±6.5	199±7.8	214±7.0	283±5.9

Values are mean ± Standard deviation over two seasons

Table 3: Fruit quality attributes of kiwifruit cultivars at harvest maturity (pooled mean)

Cultivar	Fruit Wt (g)	TSS (°Brix)	Acidity (%)	Vit C (mg/100g)	Firmness (kg/cm ²)
Hayward	78.3 a	14.2 a	1.18 c	89.4 a	6.7 a
Allison	65.7 b	12.8 b	1.34 b	76.2 b	5.9 b
Bruno	72.1 ab	13.5 ab	1.27 bc	82.7 ab	6.3 ab
Monty	58.4 c	11.7 c	1.51 a	64.8 c	5.1 c
Abbott	61.9 bc	12.1 bc	1.42 ab	69.3 bc	5.4 bc
CD (p=0.05)	8.6	1.1	0.14	9.8	0.7

Means followed by the same letter within a column do not differ at $p < 0.05$ (DMRT)

**Fig 2:** Average fruit weight (bars) and total soluble solids (line) across six kiwifruit cultivars under highland conditions

Comprehensive Interpretation

Hayward's superiority in both vegetative and fruit-quality traits aligns with its known genetic vigour, yet its longer maturity window (289 DAT) may pose a risk in regions where late-season rains coincide with harvest. Bruno emerged as the earliest maturing cultivar (267 DAT) without a steep penalty in fruit weight or TSS, suggesting that growers with shorter frost-free windows would benefit from choosing it. Monty consistently ranked lowest, pointing to poor compatibility with the site's relatively low chilling-hour accumulation. The inverse relationship between titratable acidity and TSS across cultivars followed the expected ripening physiology, where organic acid catabolism feeds sugar accumulation during the final weeks before harvest^[14].

Discussion

Hayward's tallest stature and widest canopy spread mirror reports from Italian highland orchards, where this cultivar produced the most extensive canopy when grown above 700 m elevation^[9]. The mechanism likely involves Hayward's greater leaf area, which intercepts more photosynthetically active radiation and channels assimilates into both structural

growth and fruit filling. For growers, this means Hayward demands wider spacing — the 4 m × 3 m layout used here was adequate, but denser planting would invite mutual shading.

Bruno's precocious flowering (187 DAT) contrasts with Hayward's later bloom (203 DAT) and agrees with Chilean field data placing Bruno 12-18 days ahead of Hayward under comparable latitudes^[10]. Earlier bloom carries a pollination advantage in highland sites, where insect activity declines sharply once overnight temperatures fall below 10 °C in late autumn. But it also increases frost exposure during early fruit development — a trade-off that highland growers must weigh against the benefit of earlier market entry.

The low performance of Monty was not unexpected. Monty was bred under high-chill New Zealand conditions (>600 h below 7.2 °C), and the trial site accumulated 587-624 h across both winters, below Monty's optimum. Marginal chilling delays bud break unevenly, disrupts synchrony between vegetative and reproductive flushes, and ultimately depresses fruit size^[15]. Abbott showed intermediate results, enough to warrant further observation but not enough to recommend it over Hayward or Bruno at this stage.

Ascorbic acid concentrations ranged from 64.8 to 89.4 mg 100 g⁻¹, comparable to values reported for kiwifruit grown in northern Iran's Caspian highlands [16]. Flesh firmness at harvest exceeded the 4.5 kg cm⁻² threshold that buyers require for extended shelf life, suggesting that even the weakest cultivar (Monty, 5.1 kg cm⁻²) could reach distant wholesale markets if cold-chain protocols are maintained.

Conclusion

This research set out to rank six exotic kiwifruit cultivars for their suitability to temperate highland conditions in Maule Region. After two seasons of field evaluation, Hayward emerged as the top performer for fruit weight (78.3 g), TSS (14.2 °Brix), and ascorbic acid content (89.4 mg 100 g⁻¹), while Bruno offered the advantage of earliest maturity (267 DAT) with acceptable quality scores. Monty and Abbott lagged behind on most parameters and appear less suited to sites with fewer than 650 chilling hours.

For farmers exploring crop diversification in highland belts of central Chile, Hayward remains the safest first choice, particularly when paired with Tomuri as a pollinator at a 5:1 ratio. Bruno deserves attention wherever an early-harvest window is commercially valuable. Future research should extend the evaluation to at least five seasons, incorporate consumer sensory panels, and test canopy-management interventions such as summer pruning and hydrogen cyanamide sprays to offset the chilling-hour deficit at marginal sites.

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