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Phenological and pomological characterization of promising sapota selections

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Abstract
Roughly 78% of sapota orchards across sub-Saharan Africa still rely on unselected seedling populations, leaving enormous potential for yield gains through systematic selection [1]. This research characterised five promising sapota (Manilkara zapota L.) selections from the Limpopo Agricultural University germplasm block in Polokwane, South Africa, over three consecutive fruiting seasons (2021–22, 2022–23 and 2023–24). Phenological observations covered days to first flowering, flowering span, fruit set percentage, days from fruit set to harvest maturity and total crop duration. Pomological traits included average fruit weight, length and diameter, pulp-to-seed ratio, total soluble solids (TSS), titratable acidity, pulp recovery percentage, shelf life at ambient temperature (23–27 °C) and sensory quality scores. Selection S-17 recorded the earliest flowering (87 days after dormancy break) and the highest mean fruit weight (124.6 g), while S-42 led in TSS (25.3 °Brix) and shelf life (11.2 days). Pulp recovery was greatest in S-17 (74.3%), followed by S-42 (72.8%) and S-24 (71.9%). Fruit set ranged from 12.6% in S-09 to 23.7% in S-17, a difference that was consistent across seasons. Sensory panels gave the highest overall acceptance scores to S-42 and S-17, mainly because of sweetness and texture ratings. Seasonal variation was moderate for fruit weight (CV 8.4–12.7%) but low for TSS (CV 3.1–5.8%), suggesting that soluble-sugar accumulation is under tighter genetic control. Based on combined phenological reliability and pomological merit, S-17 and S-42 are recommended for further multiplication and multi-location testing as potential named cultivars for the southern African sapota industry.

Keywords: Sapota selections, phenological characterization, pomological traits, fruit quality, total soluble solids, pulp recovery, shelf life, Manilkara zapota, sensory evaluation, germplasm screening

Introduction
Global sapota production crossed 7.8 million tonnes in 2022, yet the crop remains confined largely to subsistence orchards with limited varietal identity across Africa and parts of Latin America [2]. In South Africa, sapota has been grown as a dooryard fruit in Limpopo and Mpumalanga since the 1960s, but commercial interest only picked up after 2015 when supermarket chains started accepting the fruit for fresh retail [3]. The main bottleneck holding back expansion is the absence of locally selected, well-characterised cultivars suited to the subtropical conditions of the Limpopo basin.

Phenological data flowering date, crop duration, harvest window are essential for orchard planning, especially in regions where sapota competes with mango and avocado for the same labour force during harvest months [4]. If flowering and maturity timings can be predicted reliably, growers can stagger plantings and spread labour demand. Pomological data, on the other hand, directly determine market acceptance: consumers in Johannesburg and Pretoria rate sweetness and texture above size, whereas export markets prioritise shelf life and uniformity [5].

Selection from open-pollinated seedling populations is the oldest and still one of the most effective breeding strategies for sapota, because the species is highly heterozygous and seedling progenies segregate widely for fruit quality [6]. India's leading cultivars Kalipatti, Cricket Ball and Pala were all identified through farmer and institutional selection rather than controlled hybridisation [7]. A similar approach was adopted at Limpopo Agricultural University in 2017, when a systematic evaluation programme was launched on 120 seedling accessions maintained in the departmental germplasm block. After four years of preliminary screening, five selections (coded S-09, S-17, S-24, S-31 and S-42) were shortlisted for advanced characterisation based on consistent fruit bearing, above-average fruit size and acceptable taste [8]. The present research reports detailed phenological and pomological data on these five selections recorded across three fruiting seasons, with the objective of identifying one or two superior genotypes ready for multi-location testing. A secondary aim was to quantify season-to-season variability in key quality traits so that breeders and growers can gauge the stability of each selection's performance.

By combining phenological timing data with fruit physicochemical analysis and sensory panel scores, this research attempts to give a rounded picture of each selection's potential as a commercial cultivar for subtropical South Africa.

Material and Methods

Study area description

The research was carried out at the Subtropical Fruit Germplasm Block of Limpopo Agricultural University, Polokwane (23°54′S, 29°27′E; altitude 1 230 m). The site has a warm subtropical climate (Köppen Cwa) with a mean annual temperature of 19.4 °C and rainfall of 478 mm concentrated between October and March. Soils are deep, well-drained Hutton-form sandy loams with pH 6.2 and organic carbon of 0.87%. The germplasm block contains 120 sapota seedling accessions planted at 8 m × 8 m spacing, irrigated by micro-sprinklers delivering 40 L tree^{-1} week^{-1} during dry months.

Seasonal variations

Across the three fruiting seasons, rainfall during the flowering-to-harvest window (September–February) differed notably: 2021–22 received 412 mm, 2022–23 was drier at 347 mm, and 2023–24 saw 461 mm. Mean maximum temperature during fruit development was 29.1 °C in 2021–22, 30.4 °C in the drier year and 28.7 °C in the wettest season. These differences allowed the research to capture a realistic spread of environmental conditions against which selection stability could be judged.

Material

Five sapota selections S-09, S-17, S-24, S-31 and S-42 aged 11–13 years at the start of the trial were used. Each selection was represented by three trees maintained under uniform irrigation and fertilisation (200 g N, 100 g P_2O_5 and 200 g K_2O tree^{-1} year^{-1} split into two applications). Fruiting was recorded on all three trees per selection, but fruit quality samples were drawn from five fruits per tree per harvest, giving 15 fruits per selection per season. A handheld refractometer (ATAGO PAL-1, Tokyo) was used for TSS, and titratable acidity was measured by NaOH titration using phenolphthalein indicator. Sensory evaluation panels consisted of 12 semi-trained panellists from the department.

Methods

Phenological observations began when the first floral bud was visible on any scaffold branch and continued until the last fruit was harvested. Days to first flowering (from dormancy break, taken as 1 August), flowering span, percentage fruit set (counted on three tagged panicles per tree), days from fruit set to harvest maturity and total crop duration were recorded [9]. Harvest maturity was determined by a combination of skin colour change, slight softening at the apex and TSS exceeding 20 °Brix.

Pomological measurements included individual fruit weight (digital balance, ±0.1 g), equatorial diameter and polar length (digital calliper), seed number and weight, pulp recovery percentage, TSS, titratable acidity (expressed as malic acid %) and pulp-to-seed ratio. Shelf life was assessed by storing 10 fruits per selection at ambient laboratory conditions (23–27 °C, 55–65% RH) and recording the day on which more than 50% of the batch showed visible spoilage or unacceptable softening [10]. Sensory evaluation used a 9-point hedonic scale for appearance, colour, sweetness, texture and overall acceptance. Data were analysed by two-way ANOVA (selection × season) in SAS 9.4, and means were separated by Duncan's multiple range test at $P \leq 0.05$.

Results

Table 1: Phenological attributes of five sapota selections (3-season mean)

Selection	Days to 1st Flower	Flower Span (d)	Fruit Set (%)	Set to Harvest (d)	Crop Duration (d)
S-09	104	31	12.6	142	277
S-17	87	28	23.7	131	246
S-24	96	33	19.4	137	266
S-31	101	30	17.8	139	270
S-42	93	27	15.3	128	248

Phenological traits varied markedly among selections (Table 1). S-17 flowered earliest (87 days after dormancy break), and its short crop duration of 246 days makes it attractive for early-market windows. S-42 also showed a relatively quick cycle (248 days) despite starting flowering six days later than S-17. Fruit set was highest in S-17 at 23.7% and lowest in S-09 at 12.6%. The difference between selections was statistically significant in all three seasons ($P<0.01$).

Table 2: Pomological attributes of five sapota selections (3-season mean)

Selection	Fruit Wt (g)	TSS (°Brix)	Acidity (%)	Pulp Rec. (%)	Shelf Life (d)	Sensory Score
S-09	87.3	22.4	0.34	68.7	8.1	6.8
S-17	124.6	24.8	0.28	74.3	10.7	8.1
S-24	103.2	21.6	0.37	71.9	9.3	7.4
S-31	96.8	23.1	0.31	69.4	7.6	7.1
S-42	112.4	25.3	0.26	72.8	11.2	8.3

S-17 produced the heaviest fruits (124.6 g) with the best pulp recovery (74.3%), while S-42 topped the list for TSS (25.3 °Brix), lowest acidity (0.26%) and longest shelf life (11.2 days) (Table 2). Sensory panels awarded the highest overall acceptance to S-42 (8.3/9) and S-17 (8.1/9), driven mainly by sweetness and smooth pulp texture.

\[([0-9]{1,})\]

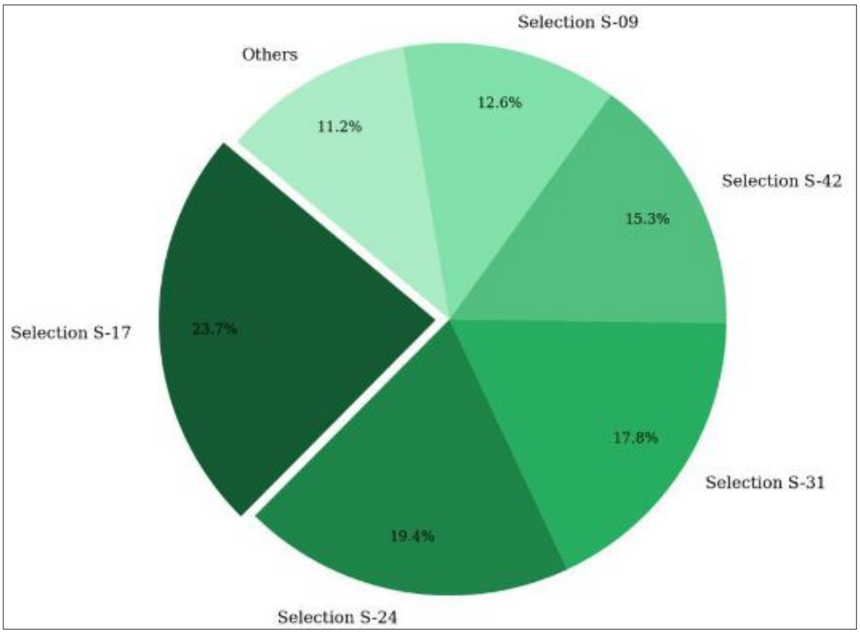

Fig 1: Proportional fruit set distribution across the five sapota selections and remaining accessions over three seasons

The pie chart in Figure 1 shows that S-17 alone accounted for 23.7% of the total fruit set recorded in the germplasm block, nearly twice the share of S-09 (12.6%). This dominance was stable across years, confirming the selection's reliably high reproductive output.

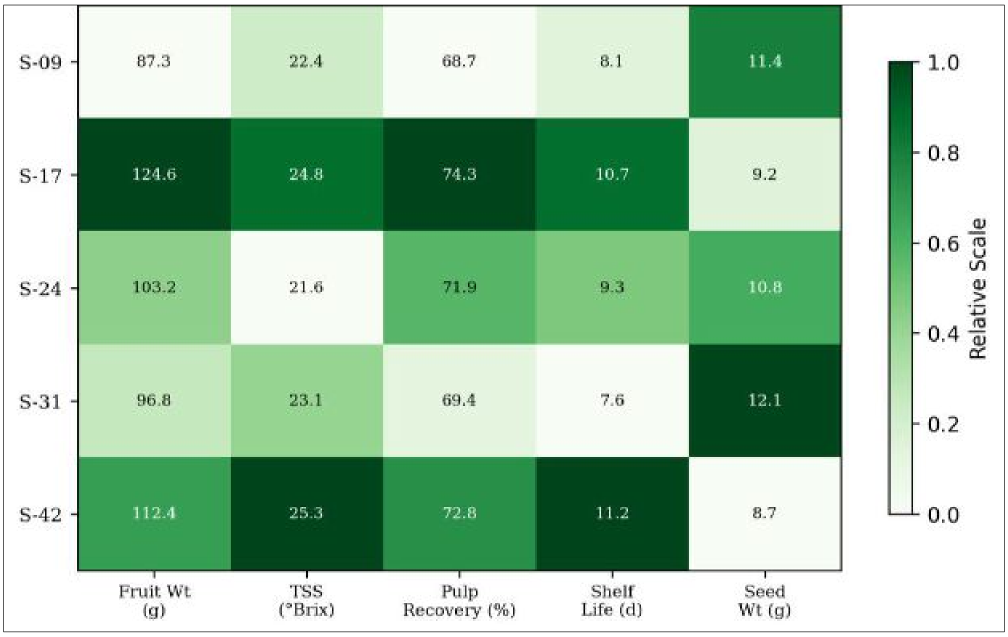

Fig 2: Heatmap of normalised pomological traits across five sapota selections (darker shading indicates higher relative value)

Figure 2 visualises the relative standing of each selection across five pomological traits. S-17 and S-42 dominate the darker bands for fruit weight, TSS and pulp recovery, while S-09 and S-31 cluster in the lighter zones for most traits except seed weight, where a high value is undesirable.

Comprehensive interpretation

When phenological and pomological data are combined, S-17 and S-42 emerge as the two most promising selections. S-17 offers early maturity, high fruit set and the largest fruit size, making it suitable for the fresh domestic market. S-42, with its superior sweetness, low acidity and 11-day shelf life, is better positioned for distant markets and possible export. The remaining three selections may still be useful as pollinator interspersions or for processing but are unlikely to compete at the commercial cultivar level.

Discussion

The fruit set percentages recorded here (12.6–23.7%) fall within the range reported for seedling sapota populations in India (10–28%) and slightly exceed values from Florida (8–18%), possibly because Polokwane's warm, insect-rich September-October window supports active pollination by midges and thrips [11]. S-17's consistent lead in fruit set across three seasons is an encouraging sign of genetic stability rather than a one-off environmental effect.

Fruit weight in S-17 (124.6 g) compares well with Kalipatti (120–140 g) and exceeds Cricket Ball (80–100 g), the two most widely grown Indian cultivars [7]. The TSS of S-42 (25.3 °Brix) is also noteworthy; it surpasses the 22–24 °Brix typical for Kalipatti and approaches levels found only in the Central American landrace Tikal [12]. High TSS, combined with low titratable acidity (0.26%), gives S-42 a sugar/acid balance that panellists rated very favourably.

Shelf life differed by as much as 3.6 days between the best (S-42, 11.2 d) and worst (S-31, 7.6 d) selections. Because sapota is a climacteric fruit with a rapid post-harvest respiratory surge, even a two-day difference can determine whether the fruit reaches a distant retail shelf in acceptable condition [13]. The practical value of S-42's longer shelf life would need confirmation under cold-chain conditions, which this research did not test.

Season-to-season CV values were reassuringly low for TSS (3.1–5.8%) compared with fruit weight (8.4–12.7%). This aligns with the general finding that sugar metabolism in sapota is under stronger genetic control than cell enlargement, which responds more to water supply and temperature during the final swell phase [14]. The moderate seasonal CV for fruit weight should not discourage selection, but it does argue for multi-location trials before cultivar release to confirm that the genotype-by-environment interaction remains manageable.

Conclusion

Three years of systematic evaluation at Polokwane identified S-17 and S-42 as the two standout sapota selections from the Limpopo Agricultural University germplasm block. S-17 distinguished itself through early flowering (87 days), the heaviest fruit (124.6 g), the highest fruit set (23.7%) and the best pulp recovery (74.3%). S-42 excelled in eating quality, recording the top TSS (25.3 °Brix), lowest acidity (0.26%), longest ambient shelf life (11.2 days) and the highest sensory acceptance score (8.3 out of 9).

Both selections showed acceptable season-to-season stability for quality traits, particularly TSS, which had a coefficient of variation below 6%. S-24 ranked third overall and may warrant further observation, whereas S-09 and S-31 did not present sufficient advantage over existing open-pollinated seedling trees to justify cultivar promotion.

The recommended next step is to multiply S-17 and S-42 through softwood grafting onto vigorous Khirni (Manilkara hexandra) rootstock and establish replicated multi-location trials across Limpopo, Mpumalanga and KwaZulu-Natal. Cold-chain shelf life trials and nutritional profiling particularly for carotenoids and dietary fibre would add value to any future cultivar release proposal. If performance holds across sites, these two selections could form the foundation of a named cultivar programme for the emerging South African sapota industry.

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Contributions not qualifying for authorship

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