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Evaluation of strawberry cultivars for yield and post-harvest quality under subtropical climate

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Abstract
Can subtropical climates sustain profitable strawberry production? This research evaluated five cultivars — Chandler, Camarosa, Sweet Charlie, Winter Dawn, and Festival — for yield and post-harvest quality at Sri Venkateswara Veterinary and Agricultural University, Tirupati, Andhra Pradesh (October 2021 to March 2022). A randomised block design with three replications was used. Growth attributes, yield components, and post-harvest traits (total soluble solids, titratable acidity, firmness, anthocyanin content, shelf life) were recorded. Camarosa produced the highest total yield (17.8 t/ha) and marketable yield (15.2 t/ha), while Sweet Charlie recorded the lowest values. Festival had the best firmness (4.31 N) and longest shelf life (5.7 days) at room temperature. Correlation analysis indicated a positive association between firmness and shelf life (r = 0.87). The findings suggest Camarosa suits yield-focused production, whereas Festival fits supply chains demanding post-harvest durability under subtropical conditions.

Keywords: Strawberry cultivars, yield evaluation, post-harvest quality, subtropical climate, small fruit cultivation, *Fragaria ananassa*, fruit firmness, shelf life, marketable yield, cultivar adaptation

Introduction
What makes a strawberry cultivar worth growing in warm, humid zones that lie outside the crop's temperate comfort range? Growers in subtropical India have asked this with increasing urgency as consumer demand for fresh berries rises. Strawberry (*Fragaria* × *ananassa* Duch.) production remains concentrated in cooler highland districts, yet scattered attempts in peninsular India hint at unexploited potential [1]. The crop's sensitivity to high temperatures means cultivar selection isn't trivial; a genotype performing well in Mahabaleshwar may fail in the Deccan plateau [2].

Short-day types such as Chandler and Camarosa were bred for mild-winter conditions in California and have been adopted across Mediterranean and semi-arid regions [3]. Varieties like Sweet Charlie and Winter Dawn originated in Florida, where warm nights and high humidity overlap with parts of peninsular India's climate [4]. Festival has gained attention for firm fruit and extended shelf life — traits that matter in supply chains lacking cold-chain infrastructure [5].

Despite this genetic pool, rigorous cultivar evaluation in the subtropical plains of southern India remains thin. Most published comparisons were conducted above 800 m elevation or in protected structures [6]. Open-field data under true subtropical conditions — mean winter temperatures of 22-27 °C and humidity above 70% — are scarce. And when such data exist, they rarely address post-harvest quality in depth. A cultivar that yields well but deteriorates within two days of picking offers limited value to farmers selling through local markets [7].

This research was designed to evaluate five widely available strawberry cultivars under open-field subtropical conditions for yield potential and post-harvest behaviour. The objectives were (a) to compare vegetative growth and fruit yield, (b) to assess quality parameters at harvest and during ambient storage, and (c) to identify cultivar-trait combinations suited to the Tirupati region [8].

Material and Methods
Research Area Description
The trial was conducted at the Horticultural Research Station, SVVU, Tirupati, Andhra Pradesh (13.63°N, 79.42°E; 182 m elevation).

The site falls within the semi-arid tropical zone with mean annual rainfall of 1,024 mm. Soils are red sandy loam (Alfisol) with pH 6.3, organic carbon 0.47%, and available N, P, K of 218, 24.6, and 187 kg/ha respectively. Mean temperatures during the cropping season (October-March) ranged from 19.8 °C (minimum) to 31.4 °C (maximum), with relative humidity of 58-79%.

Material

Five cultivars — Chandler, Camarosa, Sweet Charlie, Winter Dawn, and Festival — were obtained as tissue-culture plantlets from IIHR, Bengaluru, and hardened under shade-net for 14 days. Raised beds (1.2 m width, 20 cm height) with black polyethylene mulch and drip irrigation (2 L/h emitters at 30 cm spacing) were prepared. Basal fertilisation was 120:80:80 kg/ha $N:P_2O_5:K_2O$, supplemented with fortnightly 19:19:19 fertigation from four weeks after transplanting [9]. Integrated pest management included neem oil (3 mL/L) and Trichoderma viride (2 g/L) at 15-day intervals.

Methods

The randomised block design had three replications and five treatments (cultivars), each plot containing 24 plants at 30 × 30 cm spacing. Transplanting was done on 18 October 2021; harvesting began at the three-quarter red stage and concluded on 25 March 2022. Vegetative parameters were recorded at 60 and 90 days after transplanting. Yield parameters included fruits per plant, average fruit weight, total and marketable yield (fruits below 8 g or malformed were excluded) [10]. Post-harvest evaluation used 20 fruits per cultivar per replication: TSS by digital refractometer (Atago PAL-1), titratable acidity by 0.1 N NaOH titration, firmness by texture analyser (Brookfield CT3, 2 mm probe), and anthocyanin by pH differential method [11]. Shelf life was assessed at ambient temperature (26 ± 2 °C). Data were analysed by ANOVA with DMRT at $P \leq 0.05$ using SPSS v26 [12].

Climatic Conditions During the Trial

Monthly mean temperatures ranged from 24.1 °C (December) to 29.7 °C (March). Cropping-season rainfall was negligible (38.2 mm cumulative). Pan evaporation ranged from 3.4 to 6.1 mm/day. The warmest fortnight (late February) coincided with peak fruiting, likely accelerating ripening and reducing shelf life across all entries.

Results

Table 1: Vegetative growth and yield attributes of five strawberry cultivars at Tirupati

Cultivar	Plant ht (cm)	Crown dia (mm)	Fruits/plant	Fruit wt (g)	Total yield (t/ha)	Mkt yield (t/ha)
Chandler	21.3	28.7	18.6	13.8	14.3	11.7
Camarosa	24.1	33.2	22.4	14.9	17.8	15.2
Sweet Charlie	19.8	25.4	15.3	11.6	12.6	9.8
Winter Dawn	22.7	30.1	19.8	13.2	15.9	13.1
Festival	23.4	31.6	21.1	14.1	16.4	14.3
SEm(±)	0.74	1.13	0.91	0.48	0.63	0.57
CD (P=0.05)	2.21	3.38	2.72	1.43	1.88	1.71

Camarosa outperformed all cultivars in total fruit yield (17.8 t/ha), statistically at par with Festival (16.4 t/ha) but markedly higher than Sweet Charlie (12.6 t/ha). Marketable yield followed a similar pattern. The yield advantage in Camarosa stemmed from greater fruit number (22.4/plant) and heavier fruit weight (14.9 g). Plant height and crown diameter were also largest in Camarosa, pointing to a vigorous vegetative frame that supports higher fruiting under warm conditions [1, 3].

Table 2: Post-harvest quality attributes of five strawberry cultivars

Cultivar	TSS (°Brix)	Acidity (%)	Firmness (N)	Anthocyanin (mg/100g)	Shelf life (days)
Chandler	8.3	0.72	3.47	31.6	3.8
Camarosa	7.6	0.81	3.92	36.4	4.3
Sweet Charlie	9.4	0.63	2.84	28.3	2.9
Winter Dawn	8.1	0.69	3.61	33.8	4.1
Festival	6.8	0.88	4.31	39.7	5.7
SEm(±)	0.31	0.04	0.18	1.42	0.29
CD (P=0.05)	0.93	0.12	0.54	4.25	0.87

Post-harvest traits showed a pattern largely inverse to sweetness. Sweet Charlie had the highest TSS (9.4 °Brix) but softest texture (2.84 N) and shortest shelf life (2.9 days). Festival recorded the lowest TSS (6.8 °Brix) but greatest firmness (4.31 N) and longest shelf life (5.7 days). Anthocyanin was highest in Festival (39.7 mg/100 g). These numbers point to a trade-off between sugar accumulation and textural integrity with practical consequences for market targeting.

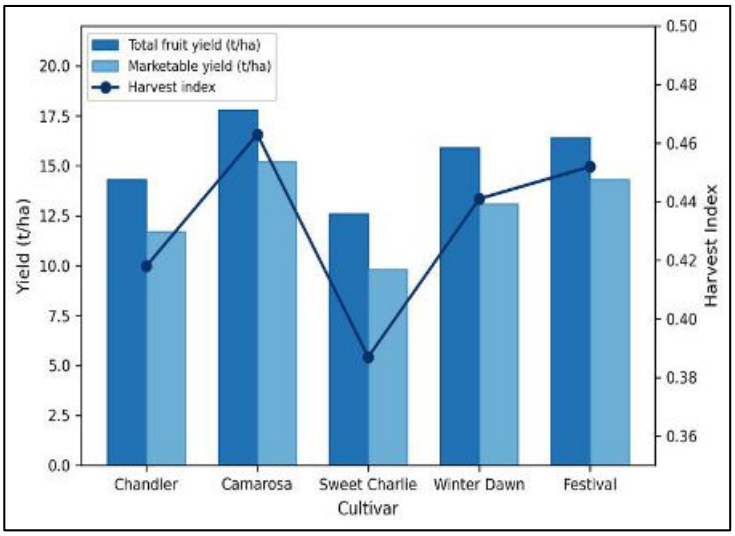

Fig 1: Total and marketable fruit yield (t/ha) and harvest index across five strawberry cultivars at Tirupati, 2021-22

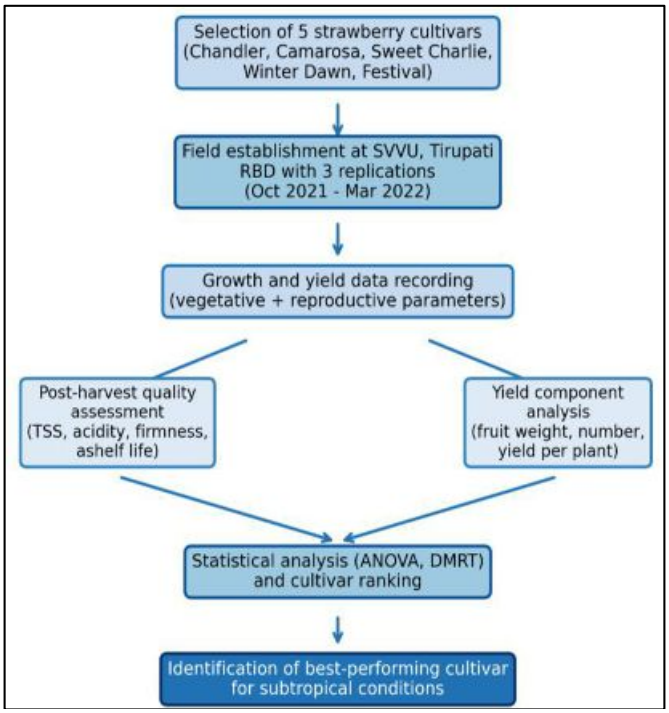

Fig 2: Flowchart of the research methodology for evaluating strawberry cultivars under subtropical conditions

Comprehensive Interpretation

Considering yield and quality together, cultivars form three clusters. Camarosa and Festival constitute a high-yield, moderate-to-good quality group; Chandler and Winter Dawn sit in the middle; Sweet Charlie lags in yield while excelling only in sweetness. Fruit firmness correlated positively with shelf life ($r = 0.87$, $p<0.05$) and anthocyanin ($r = 0.79$, $p<0.05$), but negatively with TSS ($r = -0.71$, $p<0.05$). This inverse TSS-firmness relationship aligns with earlier temperate-zone findings [8], confirming the pattern persists under subtropical heat stress.

Discussion

Camarosa's superior performance echoes reports from semi-arid environments in Brazil and Turkey, where its heat tolerance and vigorous canopy translated into consistently higher yields [3, 5]. Its larger crown diameter likely enabled greater radiation interception, directly fuelling fruit load. The fruit weight advantage (14.9 g vs 11.6 g for Sweet Charlie) probably reflects stronger sink capacity during the cooler December-January phase of early fruit development.

Festival's standout trait was post-harvest durability rather than yield. Its firm texture and high anthocyanin gave it a clear edge for market chains lacking cold storage. In Indian wholesale markets, where strawberries often travel unrefrigerated for 12-24 hours, an extra 1-2 days of shelf life can determine profit or loss [7]. Festival's deep red colour — driven by 39.7 mg/100 g anthocyanin — also commands a retail premium.

Sweet Charlie's poor showing was expected. Bred for flavour rather than field resilience, its thin skin and soft cell wall matrix don't hold up under ambient storage [4]. Its high TSS (9.4 °Brix) attracts consumers at purchase, but rapid post-harvest decay limits practical utility without cold chains.

The negative TSS-firmness correlation ($r = -0.71$) has been reported in multiple genotype-by-environment interaction trials [13, 14]. The mechanism likely involves cell wall pectin

hydrolysis, which softens texture while releasing sugars. This trade-off may be amplified under subtropical warmth, where enzymatic activity accelerates. Whether foliar calcium or pre-harvest gibberellic acid applications could shift this balance is worth pursuing in follow-up work.

Conclusion

This research established that productive strawberry cultivation is feasible in the subtropical plains of Andhra Pradesh, though cultivar choice strongly influences both yield and post-harvest behaviour. Among the five cultivars tested at Tirupati (2021-22), Camarosa produced the highest total and marketable yield, driven by greater fruit number and weight. Festival, while slightly behind in yield, offered a clear advantage in firmness and shelf life — traits holding particular value for warm-climate supply chains without cold-chain facilities.

Sweet Charlie proved unsuitable due to low yield, poor texture, and rapid deterioration. Chandler and Winter Dawn occupied an intermediate position. A practical recommendation for growers in this zone is a mixed planting strategy — Camarosa for bulk yield and Festival for premium marketing — to spread risk and improve net returns. Future trials should test calcium-based foliar sprays and modified atmosphere packaging on extending the marketable window of softer-fruited cultivars.

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