Journal of Applied Horticulture, 28(2): 542-551, 2026
https://doi.org/10.37855/jah.2026.v28i02.85
Journal of Applied Horticulture
ISSN: 0972-1045

Price realisation, profitability structure and factors influencing pomegranate cultivation: Evidence from Pandharpur and Sangola Talukas, Solapur district, Maharashtra

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Abstract

Maharashtra accounts for about 63% of India's pomegranate area, and Solapur is its principal production district. Full-cost profitability, price realisation and farmer-reported constraints remain poorly documented for Pandharpur and Sangola talukas. This study used primary data from 380 farmers (190 per taluka, 2024–25). Costs followed the CACP hierarchy. Analyses included Mann–Whitney tests, ANOVA with Tukey HSD, log-log OLS, quantile regression, Oaxaca–Blinder decomposition, sensitivity analysis and a frequency analysis of farmer-reported constraints. At Cost C2, the mean farm-level benefit–cost ratio was 1.95 in Pandharpur and 2.11 in Sangola. Net returns were Rs. 7,40,065 and Rs. 9,15,599 ha^{-1}. Imputed costs of family labour, owned-land rent and interest on fixed capital added Rs. 3.48–3.93 lakh ha^{-1} to paid-out costs. Farm size explained 26.9–27.5% of price variation ($P < 0.001$). Farms above 10 acres realised Rs. 33–49 kg^{-1} more than one-acre farms. Differences in observed characteristics statistically explained 79.5% of the inter-taluka BCR gap with Pandharpur as reference and 48.2% with Sangola as reference. Farm-gate price was the largest positive contributor in both specifications. In Sangola, the price coefficient in the yield quantile regression declined from 0.413 (Q25) to 0.254 (Q75). This pattern is consistent with the hypothesis that improved market access may benefit lower-yield farms more. Insect, pest and disease infection was the most frequently reported pre-harvest constraint (32.6% of farmers). Lack of storage (25.3%) and credit (23.2%) led marketing constraints. Pomegranate returned more per hectare and per 1,000 litres of crop water than sugarcane, soybean and rabi jowar under the assumptions used. The results support price-risk management through e-NAM, FPO-linked grading and storage, disease management and establishment-stage credit.

Key words: *Punica granatum*, price realisation, profitability structure, CACP cost hierarchy, benefit–cost ratio, farm size, market access, Oaxaca–Blinder decomposition, quantile regression, farmer-reported constraints, Solapur district, semi-arid horticulture.

Introduction

Pomegranate (*Punica granatum* L.) is an important horticultural crop particularly in India's semi-arid regions because it provides high returns under erratic rainfall and shallow soils. India produced 3.42 million tonnes from 2.69 lakh hectares in 2022–23, making it the world's largest producer (NHB, 2023). Maharashtra contributes 62.91% of the national area and 65–70% of production, with Solapur as its principal production centre (Shelake and Vhankade, 2022). Global production is led by India, Iran, China, Turkey and the USA (Melgarejo-Sánchez *et al*., 2019). The global pomegranate market (fresh fruit and processed products), valued at USD 5.6 billion in 2023, is projected to reach USD 10.6 billion by 2033 (Allied Market Research, 2024). In Solapur, the premium Bhagwa cultivar occupies more than 90% of the area because of its colour, shelf life, and aril quality.

In the present study, establishment costs were estimated at approximately Rs. 1.45–1.63 lakh ha^{-1}, and commercial yields begin after two to three years. In the present sample, fertilisers account for about 17% of full economic cost and plant-protection chemicals for about 10%. Price risk is important: Solapur APMC prices show a coefficient of variation above 60% (Kamble *et al*., 2021). Government support through the World Bank-assisted Nanaji Deshmukh Krushi Sanjivani Prakalp promotes drip irrigation and FPO development (GoM, 2018), but such interventions require farm-level evidence.

Annual cost-of-cultivation studies report benefit–cost ratios of 1.63 in Ahmednagar (Varpe et al., 2025) and 2.14 in Vidarbha (Kulkarni et al., 2019). Investment appraisals report discounted benefit–cost ratios of 2.61 in Solapur (Rede and Bhattacharyya, 2018) and 1.60 in Karnataka (Sahana et al., 2017). These investment ratios are not directly comparable with an annual Cost C2 ratio. Ratios of 1.43–1.73 are reported for Turkey (Canakci, 2010) and 5.57 for Iran (Troujeni and Rastegaripour, 2018). Ravikumar *et al*. (2015) found increasing returns to scale in Karnataka, while Hosamani *et al*. (2014) identified unexploited economies of scale in Bijapur. Disease and water scarcity remain leading constraints (Kulkarni *et al*., 2019), although pomegranate remains suitable for dryland income generation (Narayan and Chand, 2020).

Existing Solapur studies used partial cost concepts, small or single-location samples, and descriptive methods. Cost C2 estimates, inter-taluka comparisons, decomposition of the BCR gap, the farm-size price gradient and quantile regression have not been reported for the Pandharpur–Sangola belt. Farm size may explain 20–30% of price variation (Chand *et al*., 2020), while small farms face market-access disadvantages in high-value crops (Birthal et al., 2013). Quantile regression (Koenker and Bassett, 1978; Verma *et al*., 2023) and Oaxaca–Blinder decomposition (Blinder, 1973; Oaxaca, 1973; Rao and Qaim, 2011; Sauer and Latacz-Lohmann, 2015) address these issues.

Using primary data collected from 380 pomegranate farmers (190 each from Pandharpur and Sangola talukas) during 2024–25, the study was conducted to estimate the full cost of pomegranate cultivation under the CACP cost hierarchy; compare production costs, returns, benefit–cost ratios, and marketing performance between the two talukas; describe farmer-reported production and marketing constraints; assess the association of farm size and other socio-economic factors with prices and profitability; decompose the inter-taluka difference in benefit–cost ratios; and compare pomegranate with competing crops. The study applies crop comparison, a frequency analysis of farmer-reported constraints, the Mann–Whitney U test, ANOVA with Tukey HSD, OLS regression, quantile regression, Oaxaca–Blinder decomposition, sensitivity analysis and marketing-cost analysis. Its theoretical foundation combines the CACP cost-accounting framework (CSO, 2008; CACP, 2024) and a market-access perspective (Birthal et al., 2013), with farm size used as a proxy for market access and bargaining power. Since no surveyed farmer leased in land, Cost A2 equals Cost A1.

Materials and methods

Study area: The study was conducted in Pandharpur and Sangola talukas of Solapur district, Maharashtra, India (17°10'–18°32' N; 74°44'–76°15' E), situated in the semi-arid Deccan Plateau, in the Western Plateau and Hills agro-climatic region and the Western Maharashtra Scarcity Zone (ICAR-CRIDA, 2011). Normal annual rainfall in the district ranges from 524 to 707 mm (CGWB, 2013). The two talukas were selected because they collectively account for the highest pomegranate cultivation intensity in Solapur district: together they represented approximately 38 per cent of the district's registered pomegranate area in 2023–24 (DHO, Solapur, 2024). The talukas present a purposive agro-climatic contrast that enhances the study's comparative value. District soils are derived from Deccan basalt; shallow black soils cover 67.8% of the area, and medium and deep black soils the remainder (ICAR-CRIDA, 2011). Pandharpur has Bhima project canal irrigation supplementing groundwater. Sangola lies in the scarcity-prone western rainfall zone of the district (CGWB, 2013) and depends almost entirely on dri*P*-irrigated groundwater. This contrast allows us to examine whether profitability differences between the two locations are associated with differences in production or market access, a question examined through the Oaxaca–Blinder decomposition.

Sampling design and data collection: A stratified systematic random sampling design was adopted, with taluka as the stratification unit and equal allocation across strata. The sampling frame comprised the official registers of pomegranate growers maintained by the District Horticulture Office (DHO), Solapur, updated for 2023–24, which listed 7,842 registered pomegranate growers in Pandharpur (4,110) and Sangola (3,732) talukas. From each taluka, 190 farmers were selected by systematic random sampling (every k-th farmer from the alphabetically ordered DHO list, where k = frame size / 190). Under a simple random sampling approximation ($z = 1.96$, $P = 0.5$), the pooled sample of 380 gives a maximum margin of error of about ±5 per cent at 95 per cent confidence. Each taluka sample of 190 gives about ±7 per cent. Sampling fractions were 4.6% in Pandharpur and 5.1% in Sangola, so no finite population correction was applied. Equal allocation was adopted despite unequal frames (4,110 and 3,732 growers) because inter-taluka comparison was the primary objective. Data were collected through face-to-face interviews using a structured schedule administered by four trained enumerators. The schedule was pre-tested before the main survey. Data were collected for the 2024–25 agricultural year. Information collected included: farm area (acres), cultivar, irrigation source and method, all cost items (labour, inputs, machinery, marketing), quantity harvested, and farm-gate price (by lot if multiple sales occurred). Cost and production data were collected retrospectively and may contain recall error. Growers not registered with the DHO were outside the sampling frame.

CACP cost concepts: Cost of cultivation was estimated following the CACP (2024) cost concepts. Cost A1 comprises all paid-out costs: hired labour, manures, fertilisers (organic, chemical, soluble), plant protection chemicals, machinery, irrigation charges, land revenue, miscellaneous expenditure, post-harvest marketing costs (harvesting, grading, loading, transport, market fee) and depreciation of owned fixed assets. Depreciation was computed by the straight-line method over asset-specific useful lives (pumps: 10 years; drip system: 15 years; power sprayer: 7 years). Cost A2 = A1 + rent paid for leased-in land; no sample farmer leased in land, so A2 = A1. Cost B1 = A1 + interest on owned fixed capital excluding land. Cost B2 = B1 + rental value of owned land. Cost C1 = B1 + imputed value of family labour, valued at the prevailing daily agricultural wage rate for Solapur district (Rs. 350 day^{-1} for male labour; Rs. 280 day^{-1} for female labour) as notified by the District Agriculture Office for 2024–25. Cost C2 = B2 + imputed value of family labour. The rental value of owned land was reported by each farmer in the survey (median Rs. 1.11 lakh acre^{-1} yr^{-1} in Pandharpur and Rs. 1.21 lakh acre^{-1} yr^{-1} in Sangola). Cost C2 is used as the primary cost measure. It is an accounting measure of full economic cost. Its imputed components (family labour, interest on owned capital and owned-land rent) are not cash expenditure. Gross return (Rs. ha^{-1}) = total yield (kg ha^{-1}) × weighted mean farm-gate price (Rs. kg^{-1}), where the weighting accounts for multiple sales lots. The benefit–cost ratio (BCR) was computed for each farm as gross return divided by cost at the specified level. Reported BCRs are means of these farm-level ratios; ratios of mean gross return to mean cost are given in the note to Table 2.

Crop comparison and water-use efficiency: Pomegranate was benchmarked against sugarcane, soybean, and jowar (rabi), the three dominant competing crops in Solapur's semi-arid agro-climatic zone. BCR at Cost C2, net return per hectare, and net return per 1,000 litres of crop water requirement were compared. Competing crop economics were sourced from AERC Pune (2024), 'Cost of Cultivation of Principal Crops in Maharashtra: 2023–24', Agro-Economic Research Centre, Gokhale Institute of Politics and Economics, Pune (Solapur district sub-sample). Competing-crop costs, returns and BCRs at Cost C2 are reported as given in AERC (2024). Seasonal crop water requirements were taken from FAO for sugarcane (1,500–2,500 mm; FAO, 2026), soybean (450–700 mm) and sorghum (450–650 mm) (Brouwer and Heibloem, 1986). Mid-point depths were converted at 1 mm = 10,000 litres ha^{-1}. For pomegranate, the drip water requirement of fifth-year orchards in semi-arid Maharashtra (mean of three bahar seasons, 11,047 litres tree^{-1} yr^{-1}; Meshram et al., 2010) was

scaled to 741 trees ha^{-1} at 3 × 4.5 m spacing, giving 8,183 thousand litres ha^{-1} yr^{-1}. This is a gross drip application at 90% efficiency, so the comparison is conservative for pomegranate. Measured irrigation volumes were not available. The water productivity comparison is indicative only.

Farmer-reported constraints: The survey schedule recorded the main reason reported by each farmer for three constraint categories: pre-harvest losses, post-harvest and marketing losses, and natural factors affecting cultivation. Each farmer selected one reason per category from a fixed list. Frequencies and percentages were computed by taluka and for the pooled sample. Taluka differences in response distributions were tested with Pearson's chi-square test, with Cramér's V as the effect size. Responses coded as 'other' (at most 2.1% per question) were excluded from the tests.

Sensitivity analysis: Four scenarios were simulated to assess BCR robustness. Scenario A: +10% increase in all paid-out costs (Cost A1 components excluding depreciation); imputed costs held constant, reflecting their notional nature. The 10% magnitude approximates the observed coefficient of variation in A1 costs across the sample (PP: CV = 11.1%; SG: CV = 11.0%). Scenario B: −10% fall in farm-gate price; the 10% magnitude is deliberately conservative relative to the observed intra-season price CV (PP: 19.3%; SG: 26.2%), making it an underestimate of actual market risk. Scenario C: +10% increase in yield per hectare, representing achievable productivity improvement under improved management. Scenario D: combined Scenarios A and B simultaneously, representing a worst-case market stress scenario. For each scenario, BCR at Cost C2 and net return were recomputed from individual farm-level data and taluka-level mean changes reported.

Advanced statistical analyses: The following analyses were applied: (i) Mann–Whitney U test (two-tailed) with rank-biserial correlation r for taluka comparison (non-parametric, given Shapiro–Wilk $P < 0.05$); (ii) one-way ANOVA with η^2 and Tukey HSD for farm-size effects on price, BCR and marketing cost; (iii) log-log OLS with HC3 robust standard errors for price determinants (all farms reported positive marketing costs, so no zero values required adjustment): $\ln(\text{price}) = \beta0 + \beta1 \ln(\text{farm size}) + \beta2 \ln(\text{marketing cost}) + \beta3 \ln(\text{yield})$; (iv) quantile regression with ln(yield ha^{-1}) as the dependent variable, estimated at Q25, Q50, Q75 with bootstrap standard errors (500 replications); coefficients on ln(price) in the yield model are interpreted as yield elasticities with respect to price, and sums of coefficients are not interpreted as returns to scale; (v) Oaxaca–Blinder decomposition of the inter-taluka BCR gap (Blinder, 1973; Oaxaca, 1973) using Pandharpur as reference (selected as the lower-BCR taluka; sensitivity using Sangola as reference is reported in results). The decomposition assumes a linear relationship between BCR and the endowment variables; BCR was modelled as a linear function of price, yield, farm size, and marketing cost in each taluka (PP: $R^2 = 0.889$; SG: $R^2 = 0.932$; both F-significant, $p < 0.001$), as reported in Table 13; (vi) Mann–Whitney U tests for marketing cost components; and (vii) annualisation of establishment costs over a 15-year orchard life. Analyses were conducted in Python 3.12 using the following packages: scipy (v1.17), numpy (v1.26), pandas (v2.1), and statsmodels (v0.14). Given the use of multiple analytical frameworks, interpretation focuses on effect sizes (η^2, r, R^2) alongside *P*-values

Table 1. Socio-economic and farm characteristics of sample pomegranate growers, Solapur district, 2024–25

Characteristic	Pandharpur	Sangola
Sample size (n)	190	190
Average farm size (acres)	4.95 ± 4.53	5.36 ± 5.12
Average farm size (hectares)	2.00 ± 1.83	2.17 ± 2.07
Farm size distribution: Small (1 ac)	31 (16.3%)	22 (11.6%)
Farm size distribution: Medium (2–4 ac)	90 (47.4%)	91 (47.9%)
Farm size distribution: Large (5–10 ac)	49 (25.8%)	55 (28.9%)
Farm size distribution: Very large (>10 ac)	20 (10.5%)	22 (11.6%)
Predominant cultivar (Phule Bhagwa, % of farms)	95.3%	98.9%
Average yield (MT ha^{-1})	17.16 ± 6.57	17.00 ± 5.00
Average farm-gate price (Rs. kg^{-1})	89 ± 17	100 ± 26
Price range (Rs. kg^{-1})	15 – 150	12 – 170
Land ownership	All owned (100%)	All owned (100%)
Drip irrigation system installed (% of farms)	100%	100%
Farming experience of 10 years or more (% of farms)	67.4%	73.7%
Age group: 35–55 years (% of sample)	74.7%	81.6%
Education: secondary or above (%)	76.8%	70.0%
Gross return (Rs. ha^{-1})	15,48,897	17,59,343
Cost C2 (Rs. ha^{-1})	8,08,831	8,43,744
Net return at C2 (Rs. ha^{-1})	7,40,065	9,15,599
BCR at Cost C2 (mean of farm ratios)	1.949	2.113
% farmers profitable at Cost C2	89.5%	89.5%

Note: Values are means ± standard deviations where applicable. Farm-gate price ranges reflect intra-taluka variability across market channels and harvest seasons. Cost C2 = full economic cost inclusive of imputed family labour, interest on owned fixed capital and rental value of owned land. BCR = mean of individual-farm ratios of gross return to Cost C2. Farm-size classes and experience, age and education shares are from the survey schedule. Primary survey, Solapur district, 2024–25.

Table 2. Cost of cultivation, gross return, net return and BCR of pomegranate under CACP cost concepts (Rs. ha^{-1}), Solapur district, 2024–25

Cost concept	PP cost	PP gross return	PP net return	PP BCR	PP % profitable	SG cost	SG gross return	SG net return	SG BCR	SG % profitable
Cost A1	4,60,382	15,48,897	10,88,515	3.38	97.4%	4,50,611	17,59,343	13,08,731	3.94	97.9%
Cost A2*	4,60,382	15,48,897	10,88,515	3.38	97.4%	4,50,611	17,59,343	13,08,731	3.94	97.9%
Cost B1	5,04,272	15,48,897	10,44,625	3.10	97.4%	4,98,780	17,59,343	12,60,562	3.57	96.3%
Cost B2	7,74,909	15,48,897	7,73,987	2.03	91.1%	8,14,548	17,59,343	9,44,795	2.19	89.5%
Cost C1	5,38,194	15,48,897	10,10,702	2.91	96.3%	5,27,976	17,59,343	12,31,366	3.38	96.3%
Cost C2★	8,08,831	15,48,897	7,40,065	1.95	89.5%	8,43,744	17,59,343	9,15,599	2.11	89.5%

Note: A1 = paid-out costs including depreciation of owned fixed assets; A2 = A1 + rent paid for leased-in land (*A2 = A1 because no farmer leased in land); B1 = A1 + interest on owned fixed capital; B2 = B1 + rental value of owned land; C1 = B1 + imputed family labour; C2 = B2 + imputed family labour. BCR = mean of individual-farm ratios of gross return to cost. Ratio of mean gross return to mean Cost C2: PP 1.915; SG 2.085. % profitable = share of 190 farms per taluka with positive net return.★ Primary cost measure. P*P* = Pandharpur; SG = Sangola.

to reduce reliance on arbitrary significance thresholds. Significance levels: † $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$..

Results

Socio-economic profile of sample farmers: Table 1 summarises the sample profile. Average farm size was 2.00 ha (4.95 ac) in Pandharpur and 2.17 ha (5.36 ac) in Sangola; medium farms (2–4 ac) dominated both samples (47.4% PP; 47.9% SG). Phule Bhagwa accounted for 95.3% (PP) and 98.9% (SG) of sampled orchards. No farmer leased in land (Cost A2 = A1). All 380 farms reported investment in drip irrigation systems. Farm-gate prices ranged widely (Rs. 15–150 kg^{-1} PP; Rs. 12–170 kg^{-1} SG), signalling substantial intra-taluka market heterogeneity.

Cost of cultivation under CACP cost concepts

Structure and composition of Cost C2: Imputed rental value of owned land was the largest cost component: Rs. 2,70,637 ha^{-1} (33.5% of C2) in Pandharpur and Rs. 3,15,768 ha^{-1} (37.4% of C2) in Sangola (Table 3).

Table 3. Item-wise structure and composition of Cost C2 of pomegranate cultivation (Rs. ha^{-1}), Solapur district, 2024–25

Cost item	PP (Rs. ha^{-1})	PP % of C2	SG (Rs. ha^{-1})	SG % of C2
A. PAID-OUT COSTS (Cost A1)				
Hired labour	28,917	3.6%	29,035	3.4%
Manures (FYM, vermicompost)	70,895	8.8%	69,162	8.2%
Chemical and soluble fertilisers	1,41,176	17.5%	1,42,482	16.9%
Plant protection (pesticides)	88,346	10.9%	82,542	9.8%
Machinery	35,382	4.4%	34,983	4.1%
Irrigation and land revenue	11,427	1.4%	10,082	1.2%
Miscellaneous and other	38,405	4.7%	39,695	4.7%
Marketing costs (total)	25,456	3.1%	29,709	3.5%
Depreciation of owned fixed assets	20,378	2.5%	12,921	1.5%
Sub-total Cost A1	4,60,382	56.9%	4,50,611	53.4%
B. IMPUTED COSTS				
Interest on owned fixed capital	43,890	5.4%	48,169	5.7%
Rental value of owned land	2,70,637	33.5%	3,15,768	37.4%
Imputed family labour	33,922	4.2%	29,196	3.5%
TOTAL COST C2	8,08,831	100.0%	8,43,744	100.0%

Note: Depreciation is a component of Cost A1 under the CACP definitions. No farmer leased in land. Owned-land rental value as reported by each farmer in the survey. Items may not sum exactly due to rounding. P*P* = Pandharpur; SG = Sangola.

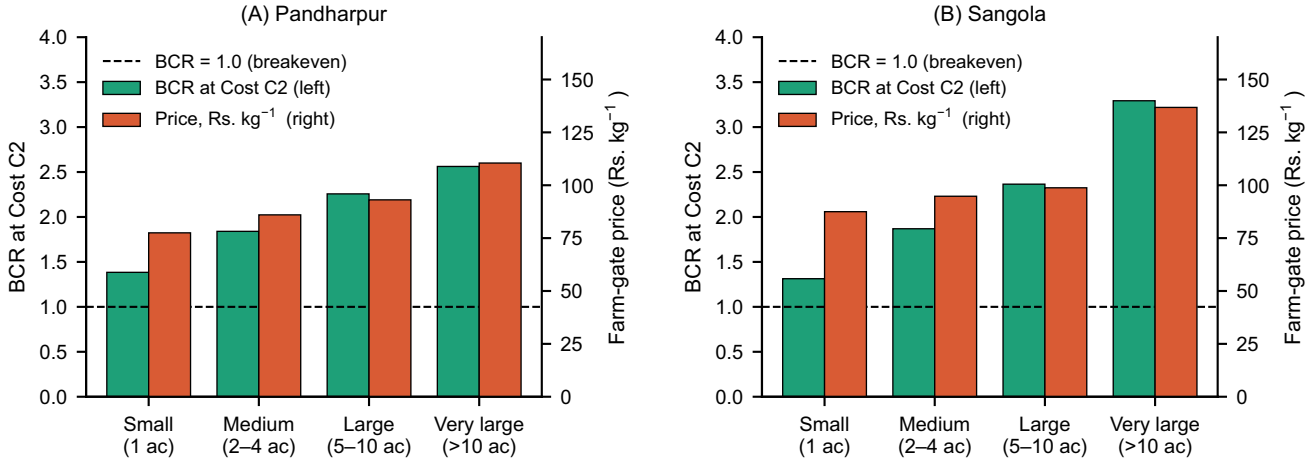


Fig. 1. Farm-size-wise BCR at Cost C2 and mean farm-gate price, Pandharpur and Sangola, 2024–25. Dashed line = BCR of 1.0 (breakeven). Exact values are given in Tables 4 and 9.

Table 4. Farm-size-wise cost, return and BCR of pomegranate at Cost C2 (Rs. ha^{-1}), Solapur district, 2024–25

Farm-size	n (PP)	PP Cost C2	PP gross return	PP net return	PP BCR	n (SG)	SG Cost C2	SG gross return	SG net return	SG BCR
Small (1 ac)	31	9,61,011	13,47,713	3,86,702	1.384	22	10,57,056	14,03,172	3,46,115	1.313
Medium (2–4 ac)	90	7,72,704	14,07,339	6,34,634	1.840	91	7,90,378	14,67,039	6,76,661	1.869
Large (5–10 ac)	49	7,61,230	16,79,229	9,17,999	2.257	55	8,24,202	19,06,599	10,82,396	2.365
Very large (>10 ac)	20	8,52,147	21,78,426	13,26,279	2.562	22	9,00,028	29,56,448	20,56,420	3.293
Overall	190	8,08,831	15,48,897	7,40,065	1.949	190	8,43,744	17,59,343	9,15,599	2.113

Note: BCR = mean of individual-farm ratios of gross return to Cost C2. Farm size in acres (1 acre = 0.405 ha). P*P* = Pandharpur; SG = Sangola.

Table 5. Comparative economics of pomegranate and competing crops, Solapur district

Crop	Cost C2 (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	BCR at C2	Crop water requirement (000 L ha^{-1} yr^{-1})	Net return per 1,000 L (Rs.)	Data source
Pomegranate (PP)	8,08,831	15,48,897	7,40,065	1.95	7,500	99	Primary survey, 2024–25
Pomegranate (SG)	8,43,744	17,59,343	9,15,599	2.11	7,500	122	Primary survey, 2024–25
Sugarcane	7,26,400	10,31,488	3,05,088	1.42	15,000	20	AERC (2024)
Soybean	1,86,240	2,43,792	57,552	1.31	4,750	12	AERC (2024)
Jowar (rabi)	1,12,800	1,33,104	20,304	1.18	1,750	12	AERC (2024)

Note: Competing-crop costs and returns as reported in AERC (2024), Solapur district, 2023–24. Crop water requirement = mid-point of ICAR-NIASM (2023) depths (pomegranate 600–900 mm; sugarcane 1,500 mm; soybean 450–500 mm; rabi jowar 150–200 mm), converted at 1 mm = 10,000 L ha^{-1}. These are total crop water requirements including rainfall; measured irrigation volumes were not available, so the comparison is indicative. Pomegranate BCR = mean of farm-level ratios.

Table 6. Farmer-reported constraints by taluka, Solapur district (n = 190 farmers per taluka, 2024–25)

Question	Reported constraint	PP n	PP %	SG n	SG %	Pooled %
Pre-harvest	Insect, pest and disease infection	61	32.1	63	33.2	32.6
	Poor climatic conditions	47	24.7	70	36.8	30.8
	Adoption of poor production techniques	41	21.6	35	18.4	20.0
	Poor harvesting procedures	39	20.5	22	11.6	16.1
Marketing	Non-availability of storage	44	23.2	52	27.4	25.3
	Lack of credit	52	27.4	36	18.9	23.2
	Perishable nature of produce	29	15.3	46	24.2	19.7
	Lack of market information	30	15.8	15	7.9	11.8
	Improper transport	18	9.5	26	13.7	11.6
	Problem of packaging	13	6.8	14	7.4	7.1
Natural	Climate change	82	43.2	62	32.6	37.9
	Insect and pest problems	20	10.5	36	18.9	14.7
	Cloudy weather	14	7.4	30	15.8	11.6
	Extreme cold	30	15.8	11	5.8	10.8
	Thunderstorm rains	27	14.2	12	6.3	10.3
	Mist	6	3.2	27	14.2	8.7
	Inadequate water supply	9	4.7	11	5.8	5.3

Note: Pre-harvest = causes of pre-harvest losses; Marketing = causes of post-harvest and marketing losses; Natural = natural factors affecting cultivation. Each farmer reported one main reason per question. Percentages are of 190 farmers per taluka. 'Other' responses (pre-harvest: PP 2; marketing: PP 4, SG 1; natural factors: PP 2, SG 1) are not shown and are excluded from the χ^2 tests. P*P* = Pandharpur; SG = Sangola.

Table 7. Sensitivity analysis of pomegranate profitability at Cost C2, Solapur district, 2024–25

Scenario	Change applied	PP BCR	PP ΔBCR	SG BCR	SG ΔBCR
Base case	No change	1.949	+0.000	2.113	+0.000
A: +10% input costs	+10% paid-out costs (excluding depreciation); imputed costs unchanged	1.846	−0.104	2.007	−0.106
B: −10% output price	−10% farm-gate price	1.754	−0.195	1.902	−0.211
C: +10% yield	+10% per-hectare yield	2.144	+0.195	2.325	+0.211
D: Combined A+B	Scenarios A and B simultaneously	1.661	−0.288	1.806	−0.307

Note: BCR = mean of farm-level ratios at Cost C2, recomputed for each farm under each scenario. ΔBCR = scenario BCR − base BCR. All scenarios keep mean BCR above 1.0. P*P* = Pandharpur (n = 190); SG = Sangola (n = 190).

Interest on owned fixed capital added Rs. 43,890 and Rs. 48,169 ha^{-1} (5.4% and 5.7% of C2). Cost C2 exceeded Cost A1 by 75.7% (PP) and 87.2% (SG). Among paid-out costs, fertilisers (17.5% and 16.9% of C2) and plant protection chemicals (10.9% and 9.8%) were the largest components.

Farm-size-wise profitability: BCR at Cost C2 rose with farm size from 1.384 (small) to 2.562 (very large) in Pandharpur, and from 1.313 to 3.293 in Sangola (Table 4; Fig. 1). Mean farm-gate price rose from Rs. 77.5 to 110.5 kg^{-1} (PP) and from Rs. 87.5 to 136.8 kg^{-1} (SG) across farm-size classes. This pattern is consistent with larger farms realising higher prices.

Comparative economics: pomegranate versus competing crops: Pomegranate BCR at Cost C2 (1.95 PP; 2.11 SG) exceeded the AERC (2024) estimates for sugarcane (1.42), soybean (1.31) and jowar (1.18) (Table 5). Net return per 1,000 litres of crop water requirement was Rs. 90 (PP) and Rs. 112 (SG), compared with Rs. 15 for sugarcane, Rs. 10 for soybean and Rs. 4 for rabi jowar. Pomegranate was financially superior under the assumptions used in this comparison.

Farmer-reported constraints: Insect, pest and disease infection was the most frequently reported cause of pre-harvest losses in Pandharpur (32.1%). In Sangola, poor climatic conditions (36.8%) narrowly exceeded insect, pest and disease infection (33.2%) (Table 6). Pooled across talukas, insect, pest and disease infection was reported most often (32.6%). Lack of credit (27.4%) and lack of storage (23.2%) were the leading causes of post-harvest and marketing losses in Pandharpur. Lack of storage (27.4%) and the perishable nature of produce (24.2%) led in Sangola. Lack of market information was reported twice as often in Pandharpur (15.8%) as in Sangola (7.9%). Climate change was the most frequently reported natural factor in both talukas (43.2% and 32.6%). Response distributions

Table 8. Mann–Whitney U test: comparison of key economic variables between Pandharpur and Sangola (n = 190 each), Solapur district, 2024–25

Variable	PP mean	PP median	SG mean	SG median	p-value	r (effect)	Effect size	Sig
Yield (t ha^{-1})	17.16	17.05	17.00	17.30	0.456	0.044	Negligible	ns
Price (Rs. kg^{-1})	89.00	90.00	100.00	100.00	<0.001	0.275	Small	***
Gross return (Rs. ha^{-1})	15,48,897	14,19,570	17,59,343	15,75,241	0.008	0.157	Small	**
Cost C2 (Rs. ha^{-1})	8,08,831	8,08,305	8,43,744	8,16,424	0.031	0.128	Small	*
Net return (Rs. ha^{-1})	7,40,065	6,43,311	9,15,599	8,09,628	0.043	0.120	Small	*
BCR at Cost C2	1.95	1.83	2.11	1.86	0.167	0.082	Negligible	ns
Hired labour (Rs. ha^{-1})	28,917	28,416	29,035	27,181	0.050	0.116	Small	†
Fertilisers (Rs. ha^{-1})	1,41,176	1,40,845	1,42,482	1,41,463	0.357	0.055	Negligible	ns
Machinery (Rs. ha^{-1})	35,382	34,964	34,983	34,894	0.851	0.011	Negligible	ns
Drip investment (Rs. ha^{-1})	38,331	38,300	38,218	38,003	0.029	0.129	Small	*
Marketing cost (Rs. ha^{-1})	25,456	22,300	29,709	26,378	<0.001	0.269	Small	***
Interest on fixed capital (Rs. ha^{-1})	43,890	41,183	48,169	40,771	0.041	0.121	Small	*
Rental value of owned land (Rs. ha^{-1})	2,70,637	2,73,042	3,15,768	2,99,605	<0.001	0.243	Small	***

Note: Mann–Whitney U test, two-tailed. r = rank-biserial correlation (negligible |r| < 0.10; small 0.10–0.29; medium 0.30–0.49; large ≥ 0.50; Cohen, 1988). †*P* < 0.10; **P* < 0.05; ***P* < 0.01; ****P* < 0.001. P*P* = Pandharpur; SG = Sangola.

Table 9. One-way ANOVA: price, BCR and marketing cost across farm-size classes, Solapur district, 2024–25

Taluka	Variable	Small (1 ac)	Medium (2–4 ac)	Large (5–10 ac)	Very large (>10 ac)	F	p-value	η^2	Sig
PP	Price (Rs. kg^{-1})	77.5	86.0	93.1	110.5	22.77	<0.001	0.269	***
PP	BCR at Cost C2	1.384	1.840	2.257	2.562	13.12	<0.001	0.175	***
PP	Marketing cost (Rs. ha^{-1})	45,326	25,946	16,463	14,490	235.00	<0.001	0.791	***
SG	Price (Rs. kg^{-1})	87.5	94.8	98.8	136.8	23.55	<0.001	0.275	***
SG	BCR at Cost C2	1.313	1.869	2.365	3.293	26.06	<0.001	0.296	***
SG	Marketing cost (Rs. ha^{-1})	46,623	31,694	25,120	16,056	72.46	<0.001	0.539	***

Note: η^2 = eta-squared (share of total variance explained by farm-size class). BCR at Cost C2. ***P < 0.001. PP = Pandharpur (n = 190); SG = Sangola (n = 190).

Table 10. Tukey HSD post-hoc pairwise price comparisons across farm-size classes, Solapur district, 2024–25

Taluka	Group i	Group j	Mean i (Rs. kg^{-1})	Mean j | (Rs. kg^{-1})	Diff.	q	p-value	Sig
PP	Small (1 ac)	Medium (2–4 ac)	77.5	86.0	−8.5	3.880	0.033	*
PP	Small (1 ac)	Large (5–10 ac)	77.5	93.1	−15.6	6.491	<0.001	***
PP	Small (1 ac)	Very large (>10 ac)	77.5	110.5	−33.0	10.980	<0.001	***
PP	Medium (2–4 ac)	Large (5–10 ac)	86.0	93.1	−7.1	3.839	0.036	*
PP	Medium (2–4 ac)	Very large (>10 ac)	86.0	110.5	−24.5	9.470	<0.001	***
PP	Large (5–10 ac)	Very large (>10 ac)	93.1	110.5	−17.4	6.254	<0.001	***
SG	Small (1 ac)	Medium (2–4 ac)	87.5	94.8	−7.4	1.957	0.511	ns
SG	Small (1 ac)	Large (5–10 ac)	87.5	98.8	−11.4	2.839	0.189	ns
SG	Small (1 ac)	Very large (>10 ac)	87.5	136.8	−49.3	10.291	<0.001	***
SG	Medium (2–4 ac)	Large (5–10 ac)	94.8	98.8	−4.0	1.470	0.727	ns
SG	Medium (2–4 ac)	Very large (>10 ac)	94.8	136.8	−41.9	11.103	<0.001	***
SG	Large (5–10 ac)	Very large (>10 ac)	98.8	136.8	−37.9	9.461	<0.001	***

Note: q = studentized range statistic; adjusted p-values from the studentized range distribution with k = 4 groups and 186 residual degrees of freedom. Diff. = Mean i − Mean j. ns = not significant; *P < 0.05; ***P < 0.001. PP = Pandharpur; SG = Sangola.

Table 11. OLS estimates of price realisation determinants for pomegranate, Pandharpur and Sangola, 2024-25

Variable	PP Coef.	PP SE	PP t-stat	PP p-value	PP Sig	PP VIF	SG Coef.	SG SE	SG t-stat	SG p-value	SG Sig	SG VIF
Intercept	4.7690	0.5788	8.239	<0.001	***	-	3.9325	0.7967	4.936	<0.001	***	-
ln(Farm size, ha)	0.0911	0.0218	4.179	<0.001	***	1.45	0.0793	0.0382	2.075	0.039	*	1.32
ln(Mktg cost, Rs. ha^{-1})	−0.0551	0.0533	−1.033	0.303	ns	2.88	−0.0264	0.0760	−0.347	0.729	ns	1.82
ln(Yield, MT ha^{-1})	0.0788	0.0449	1.758	0.080	†	1.08	0.3122	0.0697	4.482	<0.001	***	1.25
Model fit	R^2 = 0.2149; Adj R^2 = 0.2022; F = 16.970 (P < 0.001); B-P test P > 0.05 (homoskedastic)						R^2 = 0.2295; Adj R^2 = 0.2171; F = 18.472 (P < 0.001); B-P test P > 0.05 (homoskedastic)					

Note: Dependent variable = ln(farm-gate price, Rs. kg^{-1}). Coefficients are elasticities (log-log specification). HC3 heteroskedasticity-robust standard errors. VIF = Variance Inflation Factor. B-P = Breusch-Pagan test. †P < 0.10; *P < 0.05; **P < 0.01; ***P < 0.001. PP = Pandharpur (n = 190); SG = Sangola (n = 190).

Table 12. Quantile regression estimates of yield determinants for pomegranate, Pandharpur and Sangola, 2024-25

Variable	PP OLS	PP Q25	PP Q50	PP Q75	SG OLS	SG Q25	SG Q50	SG Q75
Intercept	-13.706	-15.167	-17.834	-10.860	-6.125	-6.690	-5.877	-5.645
ln (Area, ha)	0.109***	0.186***	0.113*	0.042 ns	0.121**	0.106**	0.105**	0.114***
ln(Price, Rs. kg^{-1})	0.175 ns	−0.015 ns	0.162 ns	0.060 ns	0.312***	0.413**	0.325*	0.254**
ln(Fertiliser, Rs. ha^{-1})	0.261 ns	0.349 ns	0.402 ns	−0.069 ns	0.151 ns	0.141 ns	−0.100 ns	0.091 ns
ln(Machinery, Rs. ha^{-1})	1.379**	1.618†	1.696 ns	1.543 ns	0.145 ns	0.082 ns	0.185 ns	0.247 ns
ln(Drip invest., Rs. ha^{-1})	−0.177 ns	−0.316 ns	−0.257 ns	−0.167 ns	0.393 ns	0.459 ns	0.612 ns	0.356 ns

Note: Dependent variable = ln(yield, t ha^{-1}). Coefficients on ln(price) are yield elasticities with respect to price. QR coefficients with bootstrap standard errors (500 replications, seed = 2025). OLS column uses HC3 robust SE. Sums of coefficients are not interpreted as returns to scale because the model includes output price. †P < 0.10; *P < 0.05; **P < 0.01; ***P < 0.001; ns = not significant. PP = Pandharpur; SG = Sangola.

differed significantly between talukas for all three questions (pre-harvest: χ^2 = 9.75, P = 0.021, Cramér's V = 0.16; marketing: χ^2 = 13.90, P = 0.016, V = 0.19; natural factors: χ^2 = 41.30, P < 0.001, V = 0.33).

Sensitivity analysis: Under the combined adverse scenario D (+10% input costs, −10% price), BCR remained above 1.0 in both talukas (PP: 1.661; SG: 1.806), indicating that mean profitability was maintained under the simulated stress (Table 7). Price risk (Scenario B: ΔBCR = −0.195/−0.211) was approximately twice as large as input cost risk (Scenario A: ΔBCR = −0.104/−0.106),

Table 13. Oaxaca–Blinder decomposition of the inter-taluka BCR gap, Solapur district, 2024–25

Component	Value	% of gap / Note		
Panel A: Decomposition (Pandharpur reference)				
Mean BCR: Pandharpur (PP)	1.949	Reference group		
Mean BCR: Sangola (SG)	2.113			
Total gap (SG − PP)	0.164	100.0%		
Endowment effect (observed characteristics)	0.130	79.5%		
Coefficient effect	0.034	20.5%		
Endowment share with Sangola as reference		48.2%		
Panel B: Per-variable endowment contributions (PP reference)	PP mean	SG mean	Contribution	% of gap
Farm-gate price (Rs. kg^{-1})	89.00	100.00	+0.237	+144.7%
Yield (t ha^{-1})	17.16	17.00	−0.014	−8.3%
Farm size (ha)	2.00	2.17	−0.011	−6.7%
Marketing cost (Rs. ha^{-1})	25,456	29,709	−0.082	−50.1%
Total endowment effect			+0.130	+79.5%

Note: BCR at Cost C2 (mean of farm-level ratios). BCR modelled as a linear function of price, yield, farm size and marketing cost by OLS in each taluka (PP: $R^2 = 0.889$; SG: $R^2 = 0.932$; both F-significant, $P < 0.001$). Endowment effect = part of the gap statistically explained by differences in observed characteristics; coefficient effect = part associated with differences in coefficients. Per-variable contributions sum to the total endowment effect. Results are sensitive to the reference group. Blinder (1973); Oaxaca (1973).

suggesting greater potential relevance of price-risk management interventions compared with generalised input subsidies.

Taluka comparison: Mann–Whitney U test: Yield did not differ significantly between the talukas (U = 17,256; $P = 0.456$; r = 0.044). A non-significant difference does not establish equal production efficiency. Farm-gate price was significantly higher in Sangola (Rs. 100 vs. Rs. 89 kg^{-1}; $P < 0.001$; r = 0.275). BCR at C2 did not differ significantly ($P = 0.167$; r = 0.082). Marketing cost ($P < 0.001$; r = 0.269) and imputed land rental ($P < 0.001$; r = 0.243) were significantly higher in Sangola (Table 8).

Farm-size price gradient: ANOVA and Tukey HSD: Farm size explained 26.9–27.5% of price variation (ANOVA F = 22.77/23.55, $P < 0.001$, $\eta^2 = 0.269/0.275$) and 17.5–29.6% of BCR variation; marketing cost showed the steepest gradient ($\eta^2 = 0.791$ PP; 0.539 SG), with small farms incurring Rs. 45,326–46,623 ha^{-1} versus Rs. 14,490–16,056 ha^{-1} for very large farms (Tables 9 and 10). In Pandharpur, Tukey HSD indicated significant price differences between all adjacent size classes (small–medium $P = 0.033$; medium–large $P = 0.036$; large–very large $P < 0.001$). In Sangola, only very large farms differed significantly from all other classes ($P < 0.001$); differences among small, medium and large farms were not significant ($P = 0.19$–0.73). Small farms simultaneously receive lower prices and incur higher marketing costs, a combined disadvantage associated with the BCR gradient.

Price realisation determinants: OLS regression: The log-log OLS model was significant in both talukas (PP: F = 16.97, $R^2 = 0.215$; SG: F = 18.47, $R^2 = 0.230$; all $P < 0.001$) (Table 11). Farm size was positively associated with price: a 1% larger farm area was associated with a 0.091% higher price (PP, $p < 0.001$) and 0.079% (SG, $p < 0.05$). Yield was significant in Sangola (elasticity = 0.312, $P < 0.001$), possibly reflecting quality premiums for high-throughput orchards, but only marginally so in Pandharpur (0.079, $p < 0.10$). Marketing cost was not significant in either taluka ($P > 0.30$). This is consistent with price premiums being associated with market access rather than marketing expenditure.

Quantile regression: yield determinants: In Pandharpur, farm size was positively associated with yield at the lower tail (Q25: $\beta = 0.186$, $P < 0.001$; Q50: $\beta = 0.113$, $P < 0.05$) but diminished to non-significance at Q75 ($\beta = 0.042$, $P = 0.360$), suggesting that farm size is associated with yield mainly among lower-yield farms (Table 12). Price was not significant at any quantile in Pandharpur (all $P > 0.40$), suggesting that production scale and market outcomes are relatively independent there. In Sangola, the price coefficient in the yield model was significant across all quantiles (Q25: $\beta = 0.413$, $P = 0.001$; Q50: $\beta = 0.325$, $P = 0.029$; Q75: $\beta = 0.254$, $P = 0.004$), with declining magnitude toward the upper tail. This pattern is consistent with the hypothesis that better market access may benefit lower-yield farms more; it does not establish such an effect.

BCR gap decomposition: Oaxaca–Blinder analysis: The inter-taluka BCR gap was 0.164 (SG 2.113 vs. PP 1.949). With Pandharpur as reference, differences in observed characteristics statistically explained 79.5% (0.130) of the gap, and the coefficient effect accounted for 20.5% (0.034) (Table 13). Farm-gate price was the largest positive contributor (+0.237; 144.7% of the gap). It was partly offset by higher marketing cost (−0.082; −50.1%), yield (−0.014; −8.3%) and farm size (−0.011; −6.7%). With Sangola as reference, observed characteristics explained 48.2% of the gap. The decomposition is sensitive to the choice of reference group. Farm-gate price remained the largest positive contributor in both specifications. These are statistical decompositions of a cross-sectional gap; they do not identify causal effects of market access or production efficiency.

Table 14. Marketing cost structure of pomegranate cultivation (Rs. ha^{-1}), Solapur district, 2024–25

Marketing cost component	PP (Rs. ha^{-1})	PP (% of total)	SG (Rs. ha^{-1})	SG (% of total)	U-test p-value	Sig
Harvesting	5,561	21.8%	5,168	17.4%	0.711	ns
Grading & packing	5,561	21.8%	6,248	21.0%	<0.001	***
Loading & unloading	4,535	17.8%	5,197	17.5%	0.002	**
Transport	5,631	22.1%	7,734	26.0%	<0.001	***
Market fee	4,169	16.4%	5,362	18.0%	<0.001	***
Total marketing cost	25,456	100.0%	29,709	100.0%	<0.001	***

Note: Mann–Whitney U test (two-tailed). Marketing cost as % of gross return: P*P* = 1.6%; SG = 1.7%. Marketing cost per farm size category (Pandharpur): small = Rs. 45,326 ha^{-1}; medium = Rs. 25,946 ha^{-1}; large = Rs. 16,463 ha^{-1}; very large = Rs. 14,490 ha^{-1} (ANOVA $\eta^2 = 0.791$, $P < 0.001$). ns = not significant; **$P < 0.01$; ***$P < 0.001$. P*P* = Pandharpur;

Marketing cost structure and establishment cost burden: Total marketing cost was Rs. 25,456 ha^{-1} (PP) and Rs. 29,709 ha^{-1} (SG), significantly higher in Sangola ($P < 0.001$; r = 0.269) (Table 14). Transport was the largest differentiating component (PP: Rs. 5,631; SG: Rs. 7,734; $P < 0.001$); harvesting costs did not differ ($P = 0.711$). The inverse farm-size gradient ($\eta^2 = 0.791$ PP; 0.539 SG) is consistent with per-unit post-harvest costs declining with farm throughput and with the higher BCR of large farms.

Establishment cost totalled Rs. 1,45,144 ha^{-1} (PP) and Rs. 1,63,079 ha^{-1} (SG) (Table 15). Annualised over a 15-year orchard life, this represents Rs. 9,676 and Rs. 10,872 ha^{-1} yr^{-1} or 1.20–1.29% of annual Cost C2. Lack of credit was the most frequently reported marketing-stage constraint in Pandharpur (27.4%). The establishment-cost burden appears mainly as an initial cash-flow requirement rather than a long-run cost, which is consistent with a role for credit instruments.

Table 15. Establishment cost structure of pomegranate orchards (Rs. ha^{-1}), Solapur district, 2024–25

Establishment cost item	PP (Rs. ha^{-1})	SG (Rs. ha^{-1})	U-test p-value	Sig
Land levelling	19,686	19,531	0.920	ns
Soil preparation	4,466	17,971	<0.001	***
Pipeline installation	17,079	16,153	0.786	ns
Drip irrigation system	38,331	38,218	0.029	*
Pit digging and planting	32,669	35,813	<0.001	***
Pomegranate planting material	32,914	35,392	0.026	*
Total establishment cost (Rs. ha^{-1})	1,45,144	1,63,079	–	–
Annualised (15-year orchard life, Rs. ha^{-1})	9,676	10,872	–	–
Annualised as % of Cost C2	1.20%	1.29%	–	–

Note: Mann–Whitney U test (two-tailed). Annualised cost = total cost ÷ 15-year productive orchard life. Annualised % of C2 uses mean annual Cost C2 per hectare (PP: Rs. 8,08,831; SG: Rs. 8,43,744). ns = not significant; *$P < 0.05$; ***$P < 0.001$. PP= Pandharpur; SG = Sangola.

Discussion

Pomegranate cultivation was economically viable when assessed at Cost C2, with mean farm-level BCRs of 1.95 in Pandharpur and 2.11 in Sangola. Annual cost-of-cultivation studies report 2.14 for Vidarbha (Kulkarni et al., 2019) and 1.63 for Ahmednagar (Varpe et al., 2025). Investment appraisals report 2.61 for Solapur (Rede and Bhattacharyya, 2018), but discounted ratios are not directly comparable with annual Cost C2 ratios. Differences across studies may reflect agro-climatic conditions, productivity, input costs, output prices and cost concepts. Mean BCR remained above unity in the combined stress scenario. Imputed costs of owned-land rent, family labour and interest on owned fixed capital added Rs. 3.48–3.93 lakh ha^{-1} to Cost A1, so cash-cost estimates overstate economic returns by this amount. This highlights the importance of incorporating opportunity costs when assessing profitability and designing price policies.

The Oaxaca–Blinder decomposition attributed 79.5% of the BCR gap to differences in observed characteristics with Pandharpur as reference, and 48.2% with Sangola as reference. Farm-gate price was the largest positive contributor in both specifications. Yield did not differ significantly between Pandharpur and Sangola ($P = 0.456$), whereas realised prices did ($P < 0.001$). These associations are consistent with price realisation contributing more than yield to the profitability difference; they do not establish equal production efficiency. Quantile regression showed that farm size was significant at Q25–Q50 in Pandharpur, whereas price was not significant in the yield model at any quantile. In Sangola, the price coefficient in the yield model was significant at all quantiles and declined from 0.413 at Q25 to 0.254 at Q75. Improving price realisation may matter more than yield improvement for narrowing profitability differences; this remains a hypothesis for future testing.

Marketing costs showed a strong inverse farm-size gradient ($\eta^2 = 0.791$), with small farms facing higher marketing costs while receiving lower prices. OLS results indicated that marketing expenditure itself was not a significant determinant of price. These results are consistent with price premiums being associated with market access rather than marketing expenditure. Collective marketing through FPOs may be more relevant than general marketing-cost subsidies. FPO-based aggregation, grading and improved access to remunerative markets could reduce the disadvantage faced by small growers. Farmer-reported constraints differed significantly between talukas. Insect, pest and disease infection was a leading pre-harvest concern in both talukas, credit was the leading marketing concern in Pandharpur and storage in Sangola. This supports a mix of shared and location-specific interventions.

Policy implications: The results support several policy interventions in pomegranate cultivation in Pandharpur and Sangola talukas, such as improving price realisation, reducing marketing costs, strengthening disease management, easing financial constraints at the establishment stage, and addressing taluka-specific productivity constraints. The large variation in constraints that farmers face by farm size and location warrants a differentiated policy approach.

Market integration and price stabilisation: The most important policy concern is price realisation, particularly for small and marginal growers. The price differential of Rs. 33–49 kg^{-1} between one-acre and very large farms (>10 ac) observed here is consistent with differences in market access and bargaining power. Integrating the APMC markets of Pandharpur and Sangola with e-NAM can improve price discovery, enhance market transparency and reduce excessive intermediary margins. At the same time, aggregation through Farmer Producer Organizations (FPOs) should be encouraged to help smallholders pool marketable surpluses and access higher-value marketing channels. A price stabilisation mechanism with a trigger price related to Cost C2 could also provide growers with additional protection against sharp market falls and distress sales.

FPO-linked grading and packing infrastructure: Marketing costs are substantially higher for small farms, at approximately Rs. 45,000–47,000 ha^{-1}, compared with Rs. 14,000–16,000 ha^{-1} for very large farms. The high effect size ($\eta^2 = 0.791$) indicates that farm size is strongly associated with differences in marketing costs. Decentralised grading and packing facilities linked to FPOs and co-located with cold-storage infrastructure could help small and medium growers achieve economies of scale, improve product quality and standardisation, extend the marketing window, and reduce dependence on distress sales immediately after harvest. Such facilities would also strengthen the bargaining position of producer groups in wholesale and organised retail markets.

Disease management support: Insect, pest and disease infection was the most frequently reported pre-harvest constraint in Pandharpur (32.1%) and the second most frequent in Sangola (33.2%), after poor climatic conditions (36.8%). Disease management is a shared priority, and climate risk requires attention in Sangola. Subsidised access to recommended bactericides and plant-protection inputs through horticulture extension networks should be strengthened. Weather-based disease and blight early-warning systems could provide timely information to growers and reduce unnecessary pesticide applications. In addition, the promotion of disease- and blight-tolerant pomegranate varieties, including suitable NRC Pomegranate selections, through Agricultural Technology Management Agency (ATMA) and other extension programmes should be intensified.

Reform of establishment-stage financing: The establishment cost of pomegranate orchards, estimated at Rs. 1.45–1.63 lakh ha^{-1}, represents a significant short-term cash-flow constraint for growers, despite being relatively small when distributed over the economic life of the orchard. The annualised establishment cost accounts for only about 1.20–1.29% of Cost C2, indicating that the principal constraint is the initial financing requirement rather than the long-term economic burden. Interest-free or highly concessional Kisan Credit Card loans with an appropriate three-year grace period could improve access to establishment finance. At the same time, streamlining the application and disbursement of dri*P*-irrigation subsidies under the relevant micro-irrigation programmes would reduce the initial capital burden and encourage timely adoption of efficient irrigation systems.

Taluka-differentiated productivity interventions: The results indicate that productivity constraints are not uniform across the two study areas and therefore require location-specific interventions. In Pandharpur, where farm size was associated with yield among lower-yield farms, the establishment of Custom Hiring Centres should be prioritised to improve access to mechanisation and reduce the fixed cost of machinery ownership. Soil-moisture monitoring and irrigation scheduling should also be promoted to address possible over-irrigation and improve water-use efficiency. In Sangola, where price was associated with yield across the yield distribution, policy should emphasise precision fertigation, improved input management and stronger integration with e-NAM and organised marketing channels. A combination of common state-level support measures and taluka-specific interventions would be more effective than a uniform policy package for improving the profitability and sustainability of pomegranate cultivation.

This study analysed pomegranate cultivation economics for 380 farmers in Pandharpur and Sangola talukas, Solapur district, in 2024–25. Mean farm-level BCR at Cost C2 was 1.95 (Pandharpur) and 2.11 (Sangola), with net returns of Rs. 7,40,065 and Rs. 9,15,599 ha^{-1}. Returns per hectare and per 1,000 litres of crop water exceeded those of competing crops under the assumptions used. Imputed costs added Rs. 3.48–3.93 lakh ha^{-1} to paid-out costs, so cash-cost accounting overstates profitability. Observed characteristics statistically explained 79.5% (Pandharpur reference) and 48.2% (Sangola reference) of the inter-taluka BCR gap, with farm-gate price the largest positive contributor. Farm size explained 26.9–27.5% of price variation (ANOVA, $P < 0.001$); small farms received lower prices and incurred higher marketing costs ($\eta^2 = 0.791$). Insect, pest and disease infection was the most frequently reported pre-harvest constraint, and storage and credit led marketing constraints. The results support price-risk management and e-NAM integration, FPO-linked grading and storage infrastructure, disease management, establishment-stage credit and taluka-differentiated programmes. Ethical statement: Primary data were collected with the informed consent of all respondents. No institutional ethics approval was required as the study involved voluntary, non-sensitive socio-economic survey data from adult participants. Data availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Received: March, 2026; Revised: April, 2026;
Accepted: April, 2026