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Postharvest Expenditure and Value Retention among Grape Growers in Nashik and Sangli

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ABSTRACT

The economic value of postharvest expenditure depends on whether it protects quality, limits physical loss and connects farmers with remunerative markets. This paper examines that relationship among 192 grape growers selected equally from Nashik and Sangli districts of Maharashtra during the 2025-26 grape season. Component-wise cost accounting is combined with Welch mean tests, Pearson correlation and multiple regression. Nashik growers incurred a marginally higher postharvest cost of ₹22.66 per kilogram than Sangli growers at ₹21.78, but realised a substantially higher weighted sale price, net realisation and revenue-to-cost ratio. Welch tests identified significant district differences in all principal expenditure, value-retention and loss indicators. Infrastructure, information, knowledge, formal market linkage and technology adoption were positively related to cost effectiveness at the bivariate level, although the combined adjusted evidence was mixed. Technology adoption retained a significant negative association with physical loss, while operational challenges reduced cost effectiveness and increased loss in both correlation and regression analysis. The hypotheses concerning district differences and operational challenges were supported, whereas the hypotheses concerning enabling conditions received qualified support. The findings show that low expenditure alone is an inadequate measure of postharvest efficiency. Expenditure retains value when preservation services, skills and market access operate as a connected system..

Keywords: *postharvest expenditure, value retention, grape growers, physical loss, quality discount, technology adoption....*

INTRODUCTION

Diversity on gender issues in leadership has emerged as a research area of main concern(Vieira et al., 2022), especially in Grapes retain commercial value only when the supply chain protects them after harvest. Harvesting, sorting, grading, packing, pre-cooling, storage, transportation and marketing take place within a short biological window, and failure at any stage can reduce saleable quantity or lower the grade of produce that still reaches the market. Supply-chain management therefore concerns more than the movement of a crop from farm to buyer. It involves the coordination of activities and relationships through which value is created, preserved and distributed (Lambert & Cooper, 2000). From a value-chain perspective, an expense becomes economically meaningful when it improves the farmer's ability to retain value rather than merely adding another cost item (Porter, 1985).

The problem is especially important for grapes because field heat, bruising, moisture loss, decay and delayed handling can develop rapidly. Temperature management and careful handling extend marketable life, whereas weak infrastructure and fragmented coordination increase the risk of deterioration (Kader, 2005). Traceability, grading and certification also influence market access because quality assurance has become part of the commercial transaction rather than a separate technical activity (Aung & Chang, 2014). These conditions make the composition of postharvest expenditure as important as its total amount.

The present paper examines postharvest expenditure and value retention among grape growers in Nashik and Sangli. Value retention is measured through weighted sale price, net realisation, the revenue-to-postharvest-cost ratio, physical quantity loss and quality-related price discount. The paper also assesses whether infrastructure, information, skills, technology, formal market linkages and operational challenges are associated with these outcomes. Its contribution lies in connecting component-wise postharvest accounting with two distinct forms of loss. Physical loss represents quantity that becomes unmarketable, while quality-related price loss concerns grapes that remain saleable but realise a lower price..

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2. LITERATURE REVIEW AND HYPOTHESIS

2.1 Postharvest Expenditure and Value Retention

Perishable-food chains face a joint problem of cost and time. Expenditure on handling, cooling, storage and transport can increase immediate operating cost, but insufficient expenditure can expose the crop to larger deterioration and market penalties. Risk may also propagate across stages when delayed cooling, weak packaging or transport disruption affects later operations (Deng et al., 2019). Studies of Indian fruit and vegetable chains have repeatedly linked losses with fragmented logistics, inadequate cold-chain access and weak market coordination (Negi & Anand, 2015; Osman et al., 2023). In the grape chain, pre-cooling, grading and specialised packaging are particularly relevant because they influence shelf life, visual quality and buyer acceptance (Kader, 2005).

Cost effectiveness should consequently be assessed against the value preserved after expenditure. A farmer may report a low postharvest cost because pre-cooling or cold storage is unavailable, not because the same services are being obtained more efficiently. Conversely, a higher cost may be economically defensible when it produces a larger weighted sale price, a lower cost share in revenue and a smaller loss burden. This reasoning is consistent with agricultural supply-chain research that treats planting, selling, logistics and institutional arrangements as interdependent decisions (Lambert & Cooper, 2000).

2.2 Infrastructure Technology and Market Coordination

Infrastructure is valuable only when farmers can access it at the required time and connect it with a viable marketing channel. Distance, waiting time and limited capacity can weaken the usefulness of a facility even when it exists. Technology adoption is similarly conditioned by finance, skills, maintenance and buyer requirements. Farmer organisations and coordinated marketing arrangements can reduce transaction costs, improve information and link smaller growers with modern markets, although the effectiveness of such arrangements varies considerably (Punjabi & Mukherjee, 2006). Export-oriented grape chains add further requirements relating to residue control, traceability, grading, packaging and buyer compliance (Phadke et al., 2022; Punjabi & Mukherjee, 2006).

2.3 Physical Loss and Quality Related Price Erosion

National assessments have shown that postharvest loss remains economically important across agricultural commodities (NABARD Consultancy Services, 2022). For grapes, the analytical distinction between quantity loss and quality-related price erosion is essential. Physical loss removes produce from sale, whereas quality deterioration can leave the quantity intact but move it to a lower grade or secondary market. Combining these outcomes can overstate the quantity lost and conceal the commercial cost of quality downgrading. The present framework therefore measures physical loss in percentage and kilograms per acre, and quality discount in rupees per kilogram.

2.4 Hypotheses

The following hypotheses translate the conceptual relationships into testable statistical statements. Each hypothesis is evaluated at the 5 per cent significance level. Rejection of the corresponding null hypothesis requires a probability value below .05, while the direction of the coefficient must also agree with the proposed relationship.

H1: Postharvest expenditure and value-retention indicators differ significantly between grape growers in Nashik and Sangli.

H2: Infrastructure, market information, knowledge, formal market linkages and technology adoption are positively associated with farmer cost effectiveness.

H3: Stronger postharvest conditions and technology adoption are negatively associated with physical postharvest loss.

H4: Operational challenges are negatively associated with cost effectiveness and positively associated with physical loss.

3. RESEARCH METHODOLOGY

3.1 Research Design and Sample

The study adopted a descriptive, analytical, comparative and cross-sectional design. Primary data were collected during the 2025-26 grape season from 192 grape growers, comprising 96 respondents from Nashik and 96 from Sangli. Farmers were selected through a multistage stratified procedure from four talukas in each district. Equal district samples preserved balance in the comparative analysis, while taluka selection represented major grape-producing clusters.

3.2 Measurement of Variables

Total postharvest cost was calculated as the sum of harvesting, sorting, packaging, pre-cooling, cold-storage, transportation, marketing and other postharvest expenses, expressed in rupees per kilogram. Weighted sale price incorporated domestic and export prices according to each respondent’s market shares. Net realisation was derived by deducting total postharvest cost from weighted sale price. The revenue-to-postharvest-cost ratio divided weighted sale price by total postharvest cost, while the cost share measured postharvest expenditure as a percentage of weighted sale price.

Physical loss covered harvesting, sorting and packing, transportation, and market or storage losses. It was recorded as a percentage and in kilograms per acre. The monetary value of physical loss was calculated separately. Quality-related price discount measured the reduction in realised price for produce that remained saleable after deterioration. Infrastructure, information reliability, knowledge and skills were measured through standardised ratings. Technology adoption was expressed as the percentage of identified practices adopted, while formal market linkage was coded from reported organised buyer, contract or producer-organisation connections.

3.3 Analytical Methods

The analysis used means, standard deviations and coefficients of variation for descriptive comparison. Welch independent-samples tests assessed H1 because equal variances could not be assumed for every district indicator. H2 and H3 were first examined through Pearson correlation and then checked through multiple regression after accounting for district, a composite key-factor index, technology adoption, operational challenges and export-market share. H4 was evaluated from the sign and significance of the challenge index in both the bivariate and adjusted models. The decision rule was $\alpha = .05$. A hypothesis was classified as supported when statistically significant results consistently followed the expected direction, partially supported when the bivariate and adjusted results differed, and not supported when the relevant coefficients were non-significant or contrary to expectation. Regression coefficients are interpreted as conditional associations rather than causal effects because the observations cover one agricultural season.

4. RESULTS

4.1 Sample and Farm Characteristics

Table 1 Sample and Operational Characteristics of Grape Growers

Indicator	Nashik	Sangli	Combined
Sample growers (number)	96	96	192
Grape-farming experience (years)	20.79	21.90	21.34
Total landholding (acres)	11.32	9.64	10.48
Area under grapes (acres)	8.63	6.91	7.77
Total grape production (kg/farm)	83,884	61,208	72,546
Grape productivity (kg/acre)	9,720	8,864	9,292

Source: Computed from primary survey data, 2025-26.

Note: Values other than sample size are means.

The equal allocation of 96 respondents to each district prevents the comparison from being dominated by the larger producing region. Farming experience was broadly similar, but Nashik growers operated on a larger scale: average grape area was 8.63 acres compared with 6.91 acres in Sangli, production per farm was higher by 22,676 kilograms, and productivity exceeded Sangli by 856 kilograms per acre. The contrast means that subsequent differences in postharvest outcomes cannot be attributed merely to unequal sample size.

Scale can influence postharvest decisions through several connected routes. A larger marketed volume can justify specialised packaging, frequent access to pre-cooling, negotiated transport and relationships with organised buyers. At the same time, larger output places more value at risk when handling is delayed. Nashik's higher production therefore creates both greater capacity to invest and a stronger financial incentive to preserve quality. These are logical mechanisms rather than causal findings, because farm scale, infrastructure and market orientation were observed simultaneously.

4.2 Postharvest Enabling Conditions

Table 2 Postharvest Infrastructure Information Linkages and Technology Adoption

Indicator	Nashik	Sangli	Combined
Packhouse availability (%)	87.50	73.96	80.73
Cold-storage availability (%)	81.25	54.17	67.71
Pre-cooling availability (%)	82.29	55.21	68.75
Distance to cold storage (km)	9.14	17.30	13.22
Waiting time at cold storage (hours)	5.22	9.38	7.30
Infrastructure availability rating	4.15	3.10	3.62
Infrastructure quality rating	4.02	3.01	3.52
Market-information reliability	4.00	3.01	3.51
Formal market linkage (%)	90.62	66.67	78.65
Technology adoption (%)	80.77	55.40	68.08

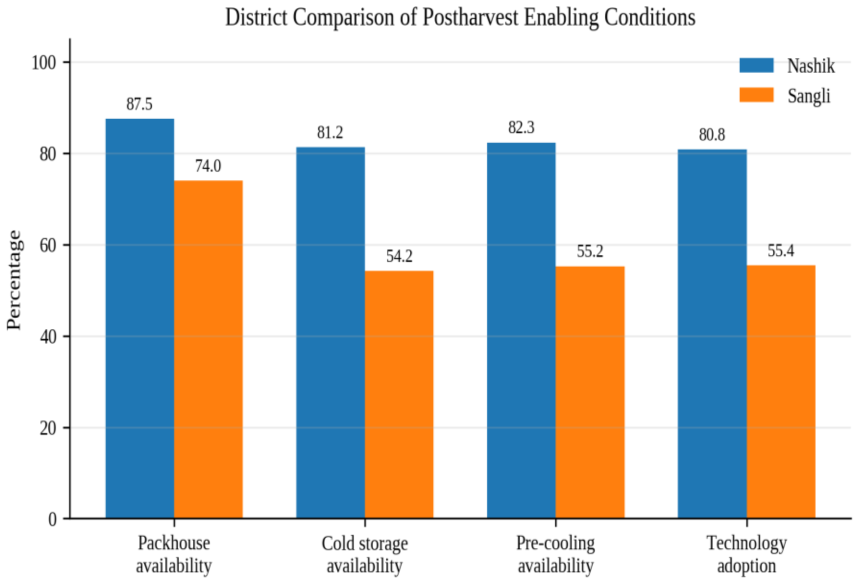
Source: Computed from primary survey data, 2025-26.

Note: Availability and formal linkage are reported as percentages. Ratings use a five-point scale.

Table 2 reveals a connected district gap rather than an isolated shortage of one facility. Packhouse availability was 13.54 percentage points higher in Nashik, whereas the gaps in cold-storage and pre-cooling availability exceeded 27 percentage points. Sangli growers travelled almost twice as far to cold storage and waited 4.16 additional hours. Technology adoption was also 25.37 percentage points lower, and formal market linkage covered only two-thirds of Sangli growers compared with more than nine-tenths in Nashik.

The comparison has a clear operational logic. A facility located farther away or reached after a long queue cannot remove field heat at the time when grapes are most vulnerable. Delayed access may also discourage farmers from using the facility, particularly when the expected market price does not compensate for transport and waiting costs. Stronger formal linkages can reduce this uncertainty by coordinating harvest time, booking, grading and dispatch. The infrastructure, technology and linkage differences therefore reinforce one another and provide a plausible explanation for the later district differences in price and loss; however, the cross-sectional design does not establish a one-way causal chain.

Figure 1 Postharvest Enabling Conditions in Nashik and Sangli



4.3 Postharvest Expenditure and Value Retention

Table 3 Postharvest Expenditure Market Realisation and Value Retention

Indicator	Nashik	Sangli	Combined
Harvesting cost (₹/kg)	4.28	4.55	4.42
Sorting cost (₹/kg)	1.79	1.95	1.87
Packaging cost (₹/kg)	8.85	8.07	8.46
Pre-cooling cost (₹/kg)	1.20	0.48	0.84
Cold-storage cost (₹/kg)	0.87	0.30	0.58
Transportation cost (₹/kg)	2.46	3.10	2.78
Total postharvest cost (₹/kg)	22.66	21.78	22.22
Domestic sale price (₹/kg)	67.95	61.76	64.86
Export sale price (₹/kg)	113.39	104.77	110.49
Weighted sale price (₹/kg)	80.78	64.88	72.83
Net realisation (₹/kg)	58.12	43.10	50.61
Revenue-to-cost ratio	3.57	2.99	3.28
Cost as share of sale price (%)	28.33	33.89	31.11

Source: Computed from primary survey data, 2025-26.

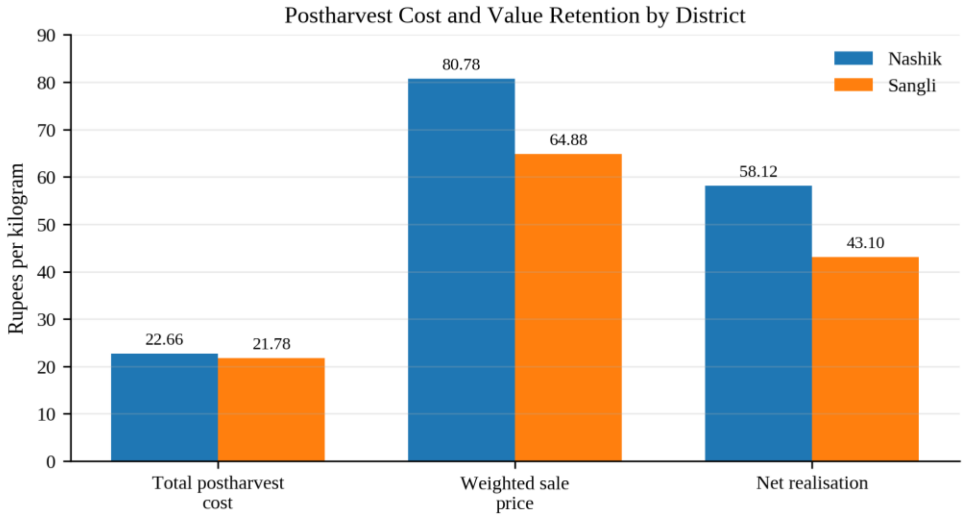
Note: Net realisation equals weighted sale price minus total postharvest cost.

The district difference in total postharvest cost was only ₹0.88 per kilogram, but the allocation of expenditure differed materially. Nashik growers spent more on packaging, pre-cooling and cold storage, whereas Sangli growers incurred higher harvesting, sorting and transportation expenses. The first group of items directly protects temperature, appearance and shelf life; the second includes necessary movement and handling costs that do not automatically create a quality premium. Similar cost totals therefore concealed different postharvest strategies.

The value consequences were much larger than the cost difference. Nashik's weighted sale price exceeded Sangli's by ₹15.90 per kilogram, and net realisation was higher by ₹15.02. The revenue-to-cost ratio reached 3.57 against 2.99, while postharvest cost absorbed a smaller share of sale value. A plausible mechanism is that preservation expenditure supported access to higher-paying buyers and reduced quality erosion, whereas Sangli's longer transport and weaker cooling access converted a larger share of spending into logistical burden. The table does not prove that every rupee spent on cooling caused the price difference, but it demonstrates that lower expenditure did not coincide with stronger value retention.

Export participation further clarifies the comparison. Nashik growers sold a larger share through export channels and received a higher weighted price even though domestic and export prices were combined according to actual market shares. Market access therefore acted as the route through which preserved quality could be monetised. Without a buyer willing to recognise grading, traceability and shelf life, preservation expenditure may reduce loss but fail to generate an immediate price premium.

Figure 2 Postharvest Cost and Value Retention by District



Note. Values are expressed in rupees per kilogram. Net realisation equals weighted sale price minus total postharvest cost.

4.4 Physical Quantity Loss and Quality Related Value Loss

Table 4 Physical Quantity Loss and Quality Related Value Loss

Indicator	Nashik	Sangli	Combined
Harvest-stage loss (%)	0.68	0.91	0.79
Sorting and packing loss (%)	0.83	1.25	1.04
Transportation loss (%)	0.46	0.86	0.66
Market or storage loss (%)	0.58	0.86	0.72
Total physical loss (%)	2.54	3.87	3.20
Total physical loss (kg/acre)	245.53	340.27	292.90
Monetary value of physical loss (₹/acre)	16,890	18,774	17,832
Quality-related price discount (₹/kg)	5.13	6.14	5.63

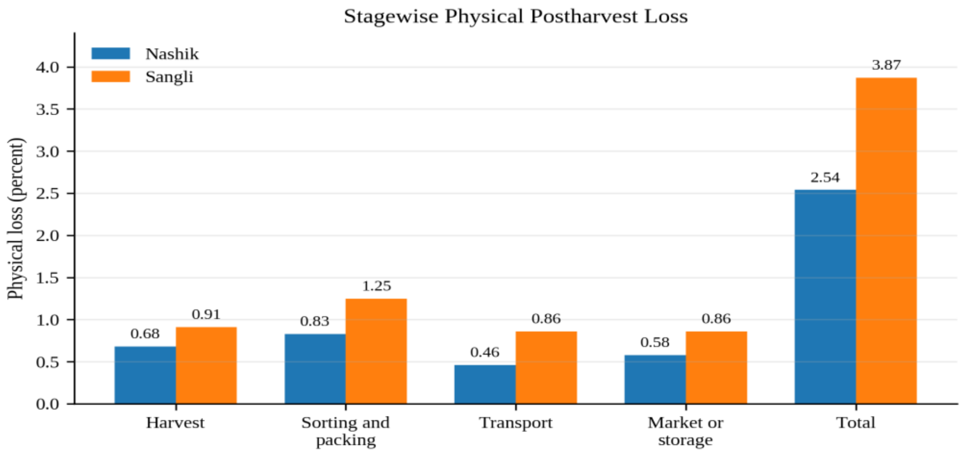
Source: Computed from primary survey data, 2025-26.

Note: Physical quantity loss and quality-related price discount are measured separately.

Sangli growers reported higher physical loss at every stage. Sorting and packing produced the largest stage difference, followed by transportation. Total loss reached 3.87 per cent in Sangli against 2.54 per cent in Nashik, equivalent to an additional 94.74 kilograms per acre. The monetary value of physical loss was also higher in Sangli despite its lower weighted price, showing that the larger quantity loss outweighed part of the price difference.

The pattern is consistent with the access conditions reported in Table 2. Longer waiting time permits field heat and moisture loss to continue, weaker packing protection increases bruising, and longer routes expose fruit to vibration and delay. These mechanisms can accumulate because damage initiated during packing may become visible only during transport or market handling. Quality-related price discount provides a second channel of erosion: Sangli's discount was ₹1.01 per kilogram higher even for grapes that remained saleable. Physical loss and price discount must therefore be treated separately, and neither can be inferred from the other.

Figure 3 Stagewise Physical Postharvest Loss by District



Note. Stage losses and total loss are expressed as percentages. Total loss is the sum of harvesting, sorting and packing, transportation, and market or storage loss.

4.5 Correlation with Cost Effectiveness and Physical Loss

Table 5 Correlation of Supply Chain Factors with Cost Effectiveness and Physical Loss

Factor	Revenue-to-cost r	p	Physical loss r	p
Infrastructure availability	0.45	<0.001	-0.55	<0.002
Infrastructure quality	0.56	<0.002	-0.59	<0.005
Market-information reliability	0.61	<0.003	-0.59	<0.005
Knowledge and skills	0.55	<0.001	-0.59	<0.004
Formal market linkage	0.30	<0.002	-0.23	0.005
Technology adoption	0.26	<0.001	-0.63	<0.004
Regulatory or policy awareness	0.07	0.320	-0.10	0.152
Operational challenge index	-0.42	<0.002	0.53	<0.001

Source: Computed from primary survey data, 2025-26.

Note: Pearson correlation coefficients are reported.

The bivariate results show a consistent pattern. Better infrastructure, more reliable market information, greater knowledge, formal linkages and wider technology adoption were associated with a higher revenue-to-cost ratio and lower physical loss. Market-information reliability recorded the strongest association with cost effectiveness (r = .61), while technology adoption had the strongest inverse association with physical loss (r = -.63). These magnitudes suggest that postharvest value is influenced by coordination and decision quality as well as by physical facilities.

The logical sequence is that reliable information helps a farmer choose the buyer, timing and quality specification before incurring postharvest expenditure. Knowledge and infrastructure then make it possible to meet those requirements. Formal linkage showed weaker coefficients, possibly because a linkage varies in quality and does not guarantee a premium transaction. Regulatory awareness was non-significant for both outcomes, indicating that information about a scheme or rule has little measurable value unless it is converted into application, training, compliance or effective use. Because the correlations pool both districts, part of their strength may reflect the broader Nashik-Sangli contrast; regression analysis is therefore necessary before drawing an adjusted interpretation.

4.6 Regression Evidence for Hypotheses 2 to 4

Table 6 Regression Estimates for Cost Effectiveness and Physical Loss

Model	Predictor	B (SE)	Beta	p
Revenue-to-cost	Sangli district	-0.172 (0.133)	-0.181	0.198
	Key-factor index	0.101 (0.078)	0.179	0.200
	Technology adoption	-0.004 (0.001)	-0.194	<0.002
	Challenge index	-0.211 (0.059)	-0.190	<0.002
	Export share	0.013 (0.001)	0.508	<0.001
Physical loss	Sangli district	0.213 (0.332)	0.094	0.523
	Key-factor index	-0.321 (0.196)	-0.239	0.103
	Technology adoption	-0.018 (0.003)	-0.375	<0.001
	Challenge index	0.735 (0.147)	0.278	<0.001
	Export share	0.006 (0.004)	0.092	0.123

Source: Computed from primary survey data, 2025-26.

Note: Revenue-to-cost model: $R^2 = 0.595$, adjusted $R^2 = 0.584$. Physical-loss model: $R^2 = 0.555$, adjusted $R^2 = 0.543$. Nashik is the district reference category.

The revenue-to-cost model explained 59.5 per cent of the observed variation and was statistically significant. Export-market share had the largest positive standardised coefficient ($\beta = .508$, $p < .001$), while operational challenges had a negative coefficient ($\beta = -.190$, $p < .002$). After the overlapping predictors were held constant, the composite key-factor index was non-significant and technology adoption changed from a positive bivariate relationship to a negative adjusted coefficient. The sign reversal indicates that technology adoption shares substantial variation with export participation, infrastructure and other operating conditions. It may also reflect the immediate cost of adoption when market access is held constant. Without diagnostic evidence, the coefficient should not be interpreted as a harmful causal effect of technology.

Taken together, the models separate financial conversion from physical preservation. Export participation was most closely associated with converting postharvest effort into revenue, whereas technology adoption was most closely associated with preventing physical loss. Operational challenges impaired both outcomes. This distinction explains why an intervention may reduce spoilage without immediately raising the revenue-to-cost ratio unless it is also connected to a remunerative market.

4.7 Hypothesis Testing

The null hypothesis for H1 states that the district means are equal on the selected postharvest expenditure and value-retention indicators. Welch tests are used because they do not require homogeneity of variance. Table 7 reports the mean difference as Nashik minus Sangli; a negative value therefore indicates a higher mean in Sangli.

Table 7 Welch Tests of District Differences in Expenditure and Value Retention

Indicator	Nashik / Sangli means	Welch test result
Total postharvest cost (₹/kg)	22.66 / 21.78	Δ = 0.88; t(189.62) = 3.52, p < .001
Weighted sale price (₹/kg)	80.78 / 64.88	Δ = 15.90; t(172.38) = 13.18, p < .002
Net realisation (₹/kg)	58.12 / 43.10	Δ = 15.02; t(177.42) = 13.09, p < .003
Revenue-to-cost ratio	3.57 / 2.99	Δ = 0.58; t(187.83) = 10.67, p < .0005
Total physical loss (%)	2.54 / 3.87	Δ = -1.33; t(149.46) = -10.09, p < .0002
Quality-related discount (₹/kg)	5.13 / 6.14	Δ = -1.01; t(187.99) = -5.86, p < .001
Export-market share (%)	27.85 / 7.16	Δ = 20.69; t(147.56) = 9.29, p < .001

Source: Computed from primary survey data, 2025-26.

Note: Mean difference is Nashik minus Sangli. The 5 per cent significance level is used.

Every reported probability value is below .05. The null hypothesis of equal district means is therefore rejected for all seven indicators, and H1 is supported. Statistical significance is accompanied by commercial significance: the ₹0.88 cost difference is small compared with the ₹15.90 weighted-price and ₹15.02 net-realisation differences. Nashik also combines lower physical and quality-related loss with a much larger export share. The evidence establishes systematic district differences, although it does not by itself identify which infrastructure or market mechanism caused them.

H2 to H4 require both directional and significance evidence. Table 8 combines the relevant Pearson coefficients with the adjusted regression coefficients. A hypothesis is treated as fully supported only when the expected relationship remains statistically significant in the adjusted model; consistent bivariate evidence with weaker adjusted evidence is classified as partial support.

Table 8 Hypothesis Tests Based on Correlation and Multiple Regression

Hypothesis and decision	Bivariate evidence	Adjusted evidence
H2 Partially supported	All specified enabling factors were positive and significant for cost effectiveness (r = .30 to .61, all p < .05).	Key-factor index: β = .179, p = .200; technology: β = -.194, p < .002; export share: β = .508, p < .001.
H3 Supported with qualification	All enabling factors were negative and significant for physical loss (r = -.23 to -.63, all p < .05).	Key-factor index: β = -.239, p = .103; technology: β = -.375, p < .001.
H4 Supported	Challenges were related to lower cost effectiveness (r = -.42, p < .002) and higher loss (r = .53, p < .001).	Cost effectiveness: β = -.190, p < .002; physical loss: β = .278, p < .001.

Source: Computed from primary survey data, 2025-26.

Note: r denotes Pearson correlation and β denotes the standardised regression coefficient.

H2 is supported at the bivariate level because each specified enabling factor has a positive and significant relationship with the revenue-to-cost ratio. The adjusted model, however, does not preserve this pattern uniformly: the key-factor index becomes non-significant and technology adoption changes sign. H2 is therefore only partially supported. The result does not invalidate infrastructure or technology; it shows that their financial return overlaps with export access and other conditions included in the model.

H3 receives stronger support. All enabling factors are negatively related to physical loss in the correlation analysis, and technology adoption remains significant in the adjusted model. The composite key-factor index is negative but non-significant after adjustment. H3 is consequently supported with qualification: technology has an independent association with lower loss, whereas the combined effect of other enabling conditions cannot be separated statistically from the remaining predictors in this specification.

H4 is fully supported. Operational challenges have the expected sign and remain statistically significant in both models. A higher challenge index is associated with a lower revenue-to-cost ratio and greater physical loss even after district, technology, the key-factor index and export share are held constant. This is the most internally consistent hypothesis result in the paper, although it remains an association derived from cross-sectional data.

5. DISCUSSION

The formal tests strengthen the descriptive argument that postharvest efficiency cannot be inferred from the smallest expenditure figure. H1 confirms systematic district differences, while H4 shows that operational frictions consistently weaken both financial and physical performance. H2 and H3 receive qualified rather than unconditional support, which is theoretically meaningful: infrastructure and technology do not create a financial return in isolation. Their contribution depends on timely use, complementary skills and access to a buyer who rewards preserved quality.

Nashik growers spent only marginally more per kilogram, but a larger share of that expenditure was directed towards packaging, pre-cooling and cold storage. These activities coincided with higher weighted prices, lower loss and a lower cost burden relative to sale value. Sangli growers spent less on preservation services but more on transportation while facing longer distances and waiting time. The commercial consequence was not merely a difference in cost; it was a difference in the value retained after cost.

The evidence is consistent with research that treats coordination and quality management as central to perishable supply chains (Aung & Chang, 2014; Lambert & Cooper, 2000). Infrastructure quality and reliable information were strongly related to cost effectiveness, while technology adoption was closely related to loss reduction. The result also supports the view that technological equipment alone is insufficient. A facility or practice generates value when it is timely, competently used and connected to a buyer who recognizes the preserved quality.

Export participation had a particularly important association with the revenue-to-cost ratio. Export markets offer higher prices but demand compliance, residue monitoring, grading, packaging and coordinated delivery. Earlier studies of Maharashtra's grape sector have similarly shown that certification and organised networks can enable market upgrading, although access is uneven among growers (Phadke et al., 2022; Punjabi & Mukherjee, 2006). The present results add an accounting dimension: the advantage becomes visible not only in the quoted export price but also in weighted price, net realisation and the cost share of revenue.

The distinction between physical loss and quality discount further clarifies the income effect. Sangli's greater physical loss reduced the quantity available for sale, while the higher quality discount reduced the value of produce that remained marketable. Managerial responses should therefore differ. Physical loss requires better handling, cooling, packing and transport discipline; quality-related price erosion additionally requires grading, moisture and appearance control, traceability, buyer communication and suitable market placement.

6. MANAGERIAL AND POLICY IMPLICATIONS

First, farmers and producer organisations should evaluate postharvest spending through a retained-value statement rather than a cost total alone. The record should show expenditure per kilogram, weighted sale price, net realisation, physical loss and quality discount. Such a statement would reveal whether a lower cost reflects efficiency or underuse of preservation services.

Second, Sangli requires stronger integration of pre-cooling, packhouse and cold-storage access. Additional capacity will have limited effect unless waiting time, booking, transportation and operating hours are coordinated. Mobile scheduling through FPOs, cooperatives or service providers could reduce delays during peak harvest. Shared grading and packing facilities would also improve access for growers who cannot justify individual investment.

Third, training should connect technology with operating practice and market purpose. Demonstrations should cover harvest timing, crate use, pre-cooling, sulphur handling, grading, packaging and records required by organised buyers. Credit or subsidy support should be linked with training and service availability so that equipment does not remain underused. Market-information systems should provide buyer-specific quality requirements, expected prices, delivery windows and rejection risks rather than only general price quotations.

7. CONCLUSION

Postharvest expenditure among grape growers becomes cost effective when it preserves saleable quantity, protects quality and supports access to better markets. Nashik growers incurred a slightly higher cost per kilogram than Sangli growers but achieved higher weighted prices, greater net realisation, a stronger revenue-to-cost ratio and lower physical and quality-related loss. Welch tests confirmed that these district differences were statistically significant. The association tests further showed that technology was closely related to physical-loss reduction, export share was the strongest adjusted correlate of cost effectiveness, and operational challenges impaired both outcomes.

The hypotheses do not produce a single mechanical explanation. H1 and H4 are supported, while H2 and H3 require qualification because some bivariate relationships weaken after adjustment. The evidence therefore favors some integrated interpretation facilities, knowledge and technology generate value when they are coordinated with timely logistics and suitable markets. The study's cross-sectional design does not permit direct causal claims, but the consistency of the challenge effects and the district contrasts provides a clear basis for targeted operational and policy action.

The results caution against policies that promote cost reduction without examining what is being reduced. Cutting expenditure on pre-cooling, storage or suitable packaging may improve an accounting total in the short term while weakening value retention. A more useful approach is to assess whether each expenditure contributes to quality preservation and market realization.

8. LIMITATIONS AND FUTURE RESEARCH

The evidence relates to one grape season and two districts. Farmer responses may contain recall error, and the analysis does not track the same farms across years. Future research should use longitudinal farm accounts, direct measurements of temperature and handling conditions, and channel-specific price data. Quasi-experimental evaluation of shared pre-cooling, digital booking or training interventions would help determine whether the observed associations translate into causal improvements in loss reduction and farmer income.

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