



RESEARCH ARTICLE

Pre- and post-harvest losses in Nendran banana supply chain: Evidence from Southwest India

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Received: 20 February 2026; Accepted: 05 May 2026; Available online: Version 1.0: 21 June 2026

Cite this article: Mangaiyarkarasi N, Chitra P, Prema A, Seenath P, Dicto JM, Shiva KN. Pre- and post-harvest losses in Nendran banana supply chain: Evidence from Southwest India. *Plant Science Today*. 2026; 13(sp2): 1-9. <https://doi.org/10.14719/pst.14178>

Abstract

Banana is an important fruit in Kerala, with Nendran being the major commercially grown variety. The losses occurring from various stages of production and post-production reduce effective output and weaken the marketing efficiency along the supply chain. The present study examines pre- and post-harvest losses along the Nendran banana supply chain in Kerala using primary data from 200 respondents comprising farmers, wholesalers, transporters and retailers in Central Kerala. Losses were quantified using a standard percentage loss approach and the determinants were analysed using a multiple regression model. The results indicated that the total losses amounted to 42.11 %, reflecting substantial inefficiencies across the supply chain. Pre-harvest losses at the farm level accounted for 10.11 %, mainly due to weather shocks and pest and disease incidence. Post-harvest losses showed an increasing trend along the supply chain, with a maximum at the retailer stage (15.51 %), followed by wholesalers (8.56 %). The losses recorded during transportation (4.39 %) and post-harvest (3.54 %) stages in the field were relatively lower. Climatic shocks and pest incidence were found to be significantly increasing the losses, while improved packaging quality, higher experience of farmers and the scale of operation helped to reduce the losses. Regression analysis confirmed that retailer-level losses were relatively higher than observed at other stages. The findings highlight the need for targeted stage-specific interventions to reduce losses and improve supply chain efficiency.

Keywords: Nendran; pooled regression; post-harvest losses; pre-harvest losses; supply chain

Introduction

Food losses have become a global issue affecting food security, resource use efficiency and environmental sustainability (1). Recent estimates showed that almost one-third of food produced for human consumption is lost or wasted annually, resulting in economic cost of over USD 1 trillion worldwide (2). A substantial share of these losses occurs with highly perishable commodities such as fruits and vegetables due to their biological nature, handling sensitivity and inadequate post-harvest infrastructure (1).

Banana (*Musa spp.*), belongs to the family Musaceae is one of the most widely cultivated and economically important fruit crops in the tropics, contributing significantly to food security, employment and income generation (3). Rich in carbohydrates, vitamins and essential minerals, banana serves both as a staple food and commercial crop in many developing countries (4, 5). India is the world's largest producer of banana, accounting for nearly one-fourth of the global production (6). Despite this, a considerable share of the produce is lost before reaching consumers. Studies reveal that post-harvest losses in fruits and vegetables in India exceed ₹90000 crore annually, which significantly reduces farmer income and marketing efficiency. Such losses are more pronounced in traditional marketing

channels where produce passes through multiple intermediaries in the absence of cold-chain infrastructure (7).

In Kerala, Nendran (AAB) banana holds a significant place due to its culinary, cultural and commercial importance. The variety commands premium market demand in both fresh and processed markets. However, banana cultivation in the state is dominated by small holders facing high input cost and climatic uncertainties. Frequent price fluctuations and delays in marketing further increases the risk of economic losses along the supply chain (8). Losses in banana occur both before harvesting due to climatic shocks, pests and management constraints and after harvesting due to mechanical damage, improper handling and storage limitations and market delays (9–14). Since these losses occur across different stakeholders, the total loss is often underestimated when individual stages are evaluated separately (15, 16).

Earlier studies on banana losses often focussed on either pre-harvest or post-harvest stages separately, thereby constraining a comprehensive understanding of losses across the supply chain (17–20). Only limited research, track losses from farm to retail while also accounting for market problems such as price fluctuations and infrastructure limitations (21). An integrated

assessment of production and marketing stages is essential to identify the key loss points and design targeted interventions. Against this background, the present study estimated the pre- and post-harvest losses of Nendran banana across major stages of the supply chain-farmers, wholesalers, transporters and retailers. It further analyses the determinants of losses and constraints faced by intermediaries to identify stage-specific strategies to enhance supply chain efficiency and reducing wastage.

Materials and Methods

Study area

A multistage purposive-cum-random sampling technique was employed for the study. In the first stage, the Central districts of Palakkad and Ernakulam in Kerala were purposively selected due to having the largest area under Nendran banana cultivation (Fig. 1). In the subsequent stage, 70 farmers, 10 wholesalers, 5 transporters and 15 retailers were selected randomly from each district, ensuring adequate representation of all key stakeholders across the supply chain resulting in a sample size of 200.

Quantitative analysis

Information on pre- and post-harvest losses was obtained through a structured survey using a recall-based approach. Farmers, wholesalers, transporters and retailers reported the average quantity handled and quantity lost at each stage during a specified reference period.

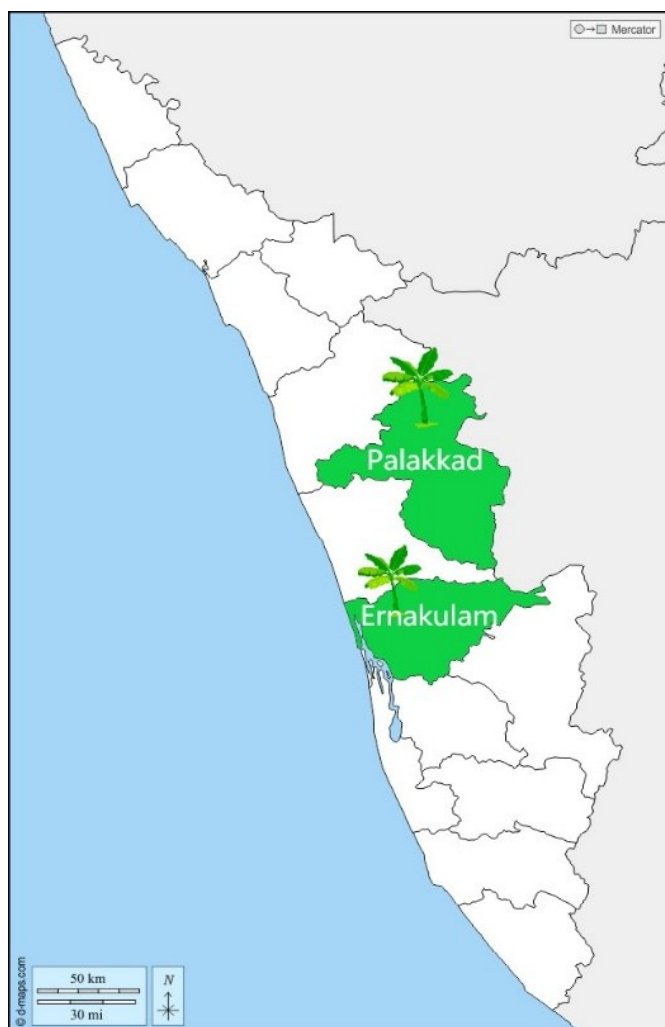


Fig. 1. Study area showing selected districts in Kerala [Source: d-maps.com (2007–26)].

Quantification of pre- and post-harvest losses

The pre-harvest and post-harvest losses were standardised into percentage terms by relating each type of loss to its respective base quantity pre-harvest losses were measured as the proportion of suckers lost before harvesting relative to total number of plants maintained in the field. Post-harvest losses were measured as weight loss (tonnes) relative to the quantity handled at each subsequent supply chain stage. Since losses at different stages occur in different physical units, all losses were standardised and expressed as percentage losses to enable comparability across stages of the supply chain.

At each stage of supply chain, percentage loss was computed as the ratio of the mean quantity of produce lost to the mean total quantity handled, expressed as a percentage, using the following formula (22).

$$\text{Percentage loss (\%)} = \frac{Q}{TQ} \times 100$$

Where,

Q = mean quantity of Nendran lost (damaged or discarded) per year

TQ = mean total quantity of Nendran handled per year

Determinants of pre- and post-harvest losses

A regression model with stage dummies was employed to identify the factors affecting the magnitude of losses across different supply chain stages.

The functional form of the model is specified as:

$$\ln(\text{Loss}_i) = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + \beta_7 D_1 + \beta_8 D_2 + \beta_9 D_3 + \beta_{10} D_4 + \varepsilon_i$$

Where,

$\ln(\text{Loss}_i)$ = Natural logarithm of percentage loss for the i^{th} respondent

β_0 = Intercept

$\beta_1 - \beta_{10}$ = Coefficients of estimates in the model

Z_1 = Climate shock (1= experienced climate shock; 0 = otherwise)

Z_2 = Pest incidence (1= pest/disease incidence; 0 = otherwise)

Z_3 = Packaging quality (1=improved; 0=otherwise)

Z_4 = Distance [log of distance (km)]

Z_5 = Experience (no. of years)

Z_6 = Scale of operation [natural log of quantity handled (tonnes/yr)]

D_1 = Dummy Farm post (1= farm post-harvest stage; 0 = otherwise)

D_2 = Dummy Wholesaler (1= Wholesaler stage; 0 = otherwise)

D_3 = Dummy Retailer (1= Retailer stage; 0 = otherwise)

D_4 = Dummy Transporter (1= Transporter stage; 0 = otherwise)

ε_i = Error term

Garrett's ranking technique

The challenges faced by intermediaries in the Nendran supply chain were identified and prioritised using Garrett's ranking technique.

The percentage position was computed using the following formula

$$\text{Percentage position} = \frac{100 (R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij} = rank assigned to the i^{th} challenge by the j^{th} respondent

N_j = total number of challenges ranked by the j^{th} respondent

Results and Discussion

Quantification of pre- and post-harvest losses along the supply chain

Quantification of pre-harvest losses at field level

Table 1 presents the extent of pre-harvest losses in Nendran banana at the field level. On average, each farm planted about 1722 suckers, of which nearly 10.11 % were lost before harvest. Weather-related shocks were identified as the most significant contributor to pre-harvest losses, accounting for 6.45 % of the total loss and nearly 64 % of overall pre-harvest damage. These results indicate that the Nendran banana is highly vulnerable to Kerala's monsoon, where heavy rainfall, floods and strong winds often result in lodging or uprooting of plants (23). This suggests that straightforward interventions such as improved drainage, wind protection or raised beds could help reduce such losses.

Pest and disease incidence accounted for 1.86 % to total losses, representing about 18 % of the overall pre-harvest loss. Infestations by pests and diseases such as rhizome weevil, pseudo stem borer, bunchy top and panama wilt considerably affect plant survival. Inadequate plant protection practices increase these losses (24), showing that effective pest and disease management could help plants survive better in the field. Losses from management and labour constraints (0.70 %), poor-quality planting material (0.58 %) and animal damage (0.52 %) were relatively small but showed certain inefficiencies on the farm. Labour shortages and higher wages, as noted in earlier studies (25), can delay essential farm activities, which in turn affect plant health and make crops more vulnerable to environmental stresses.

Earlier studies in Africa reported pre-harvest losses of 31.6 % in banana (21) while the current study in Kerala recorded 10.11 %. This key difference likely reflects regional variations in climate, pest and farm management rather than a direct improvement in losses.

Table 1. Pre-harvest losses in Nendran at field level

Sl. No.	Factors responsible for losses	Average quantity handled (No. of suckers planted)	Average quantity loss (No. of plants lost)	Percentage loss (%)
1.	Pest and disease incidence	1722	32	1.86 (18)
2.	Weather shocks	1722	111	6.45 (64)
3.	Animal damage	1722	9	0.52 (5)
4.	Poor planting material	1722	10	0.58 (6)
5.	Management and labour constraints	1722	12	0.70(7)
Percentage loss at field level (%)				10.11 (100)

Figures in parentheses indicate percentage to total.

Table 2. Post-harvest losses in Nendran at field level

Sl. No.	Factors responsible for losses	Average quantity handled (tonnes)	Average quantity loss	Percentage loss (%)
1.	Mechanical and physical damage	32	0.08	0.25 (7)
2.	Improper harvesting practices	32	0.32	1.00 (28)
3.	Delays between harvest and dispatch	32	0.53	1.66 (47)
4.	Poor on-farm packaging	32	0.05	0.16 (4)
5.	Pest and disease incidence	32	0.11	0.34 (10)
6.	Lack of on-farm storage/ripening facilities	32	0.04	0.13 (4)
Percentage loss at field level (%)				3.54 (100)

Figures in parentheses indicate percentage to total.

Overall, the results indicate that climatic risks and biological stress are the primary drivers of pre-harvest losses in Nendran banana cultivation. These findings underscore the importance of adopting climate-resilient production practices, ensuring the use of quality planting material and strengthening on-farm management to minimise losses and enhance the resilience of small holder banana cultivation.

Quantification of post-harvest losses

Post-harvest losses at field level

Post-harvest losses occurring at the field level are summarised in Table 2. These losses accounted for about 3.54 % of the total production. Among the different causes, delays between harvesting and dispatch emerged as the largest share of losses, contributing 1.66 % of total output and nearly 47 % of overall field-level post-harvest losses. This is primarily due to the climacteric nature of Nendran banana, which undergoes rapid ripening characterised by increased respiration and ethylene production after harvest. Prolonged exposure to ambient tropical conditions during delays accelerates senescence, moisture loss and quality deterioration, thereby increasing the extent of losses. Delays caused by labour shortages, transport problems and market uncertainties accelerate banana ripening and reduce fruit quality (26, 27). This shows that harvesting and marketing on time are key points in the supply chain, where even short delays can increase losses.

Improper harvesting practices accounted for 1.00 % of the loss, accounting for about 28 % of total post-harvest losses at the farm level. These losses mainly resulted from harvesting at inappropriate maturity stages, rough cutting of bunches, dropping of bunches during detachment, latex staining and finger breakage caused by inadequate skill and lack of proper harvesting tools. This highlights that handling errors and limited skills lead to mechanical damage, emphasising the need for training and improved harvesting tools (28).

Other factors including pest and disease incidence (0.34 %), mechanical and physical damage (0.25 %), inadequate on-farm packaging (0.16 %) and the absence of storage and ripening facilities (0.13 %) accounted for relatively small shares of total loss, however it remains economically important, as it leads to quality deterioration and distress sales thereby reducing farm income disproportionately. This shows that small losses at different stages of farm handling can

add up to major economic impacts, which is consistent with findings from tropical fruit supply chains (29).

Farm level losses in this study (3.54 %) are lower than the national average of 5.17 % (7), suggesting better on-farm handling. Losses were higher in Sri Lanka (9 %) due to delayed marketing and poor storage (30) and in Central Ethiopia (17 %) from mechanical damage and premature harvesting (31) while Bihar reported 2.9 % losses, like Kerala (32). This shows that labour, skills and infrastructure strongly influence post-harvest losses. Overall, these losses are mainly caused by handling and timing rather than environmental factors. Improving harvesting practices, training workers and ensuring timely transport and storage can reduce losses, protect fruit quality and increase profitability.

Post-harvest losses at wholesaler level

Table 3 presents post-harvest losses at wholesaler level. The results indicate that losses at this stage reached 8.56 %, pointing to considerable deterioration during bulk handling, storage and movement of bananas. Mechanical and physical damage emerged as the most important source of loss, accounting for 1.93 % of the total quantity handled. Losses due to pest and disease incidence were almost equally high at 1.85 %. Together, these two factors account for 45 % of total losses at the wholesaler stage. Frequent loading/unloading and stacking without protective packaging often cause bruising, compression and breakage (2, 33).

Poor packaging (1.60 %), transport and handling constraints (1.18 %) and lack of cold-chain infrastructure (1.09 %) indicate that a major share of losses at this stage arise from weaknesses in logistics rather than from biological spoilage alone. The absence of temperature-controlled storage accelerates ripening, while market delays (0.92 %) reduce quality and prolong holding time (34).

Compared to other studies, these losses are moderate. Wholesale losses of 35.9 % in some regions were mainly due to mechanical damage and poor storage (35), while 27 % was reported in Central Ethiopia (31). Losses of 6.65 % in Karnataka and 2.52 % in Tamil Nadu reflect more efficient handling (17, 36). In Sri Lanka, 5.4 % of losses occurred at the wholesale stage, showing a similar trend of increasing losses beyond the farm gate (30). Overall, wholesaler-level losses are primarily driven more by handling and logistics inefficiencies rather than by biological spoilage. Improving

packaging, transport and cold-chain infrastructure can substantially reduce losses and preserve fruit quality.

Post-harvest losses at transporter level

Post-harvest losses incurred during transportation are detailed in Table 4. The findings show that losses at the transporter level amounted to 4.39 % of the total quantity moved. Transport and handling issues were the most prominent contributors to loss, accounting for 2.67 % and representing about 61 % of the total losses at this stage. Poor roads, overloading and lack of cushioning expose bunches to vibration, resulting in substantial physical damage (37, 38).

Other losses came from inadequate packaging practices (0.42 %), mechanical damage during loading and unloading (0.42 %) and absence of cold-chain facilities (0.33 %), which accelerate ripening and spoilage (13). Pest and disease incidence accounted for 0.38 %, particularly during long-distance movement.

These losses are higher than the 1.14 % reported across India, likely due to differences in transport distance, road conditions and vehicle type (39). Studies also show that transport damage is a key contributor to losses at wholesale and retail stages, caused by vibration, compression and lack of protective measures (4, 35). At the transporter level, losses are largely caused by poor handling and weak infrastructure. Using better packaging, cushioning and cold-chain facilities can significantly reduce losses and preserve fruit quality.

Post-harvest losses at retailer level

The post-harvest losses at the retail level accounted for the highest percentage of all the post-harvest stages, amounting to 15.51 % (Table 5). Mechanical and physical damage (4.23 %) was the major factor, followed by poor packaging (3.10 %) and pest and disease incidence (2.54 %). These results indicate that losses at this stage are primarily driven by handling intensity and storage limitations. Retailers frequently manage quantities necessitating frequent display and reorganisation, which increases the chances of damage (2, 6).

Losses due to transport and handling constraints (2.54 %), lack of cold-chain infrastructure (1.97 %) and market-related delays (1.13 %) further highlight the susceptibility of bananas at the retail

Table 3. Post-harvest losses in Nendran at wholesaler level

Sl. No.	Factors responsible for losses	Average quantity handled (tonnes)	Average quantity loss (tonnes)	Percentage loss (%)
1.	Mechanical and physical damage	11.91	0.23	1.93 (23)
2.	Pest and disease incidence	11.91	0.22	1.85 (22)
3.	Poor packaging	11.91	0.19	1.60 (18)
4.	Lack of cold-chain infrastructure	11.91	0.13	1.09 (13)
5.	Transport and handling constraints	11.91	0.14	1.18 (13)
6.	Market-related delays	11.91	0.11	0.92 (11)
Percentage loss at wholesaler level (%)				8.56 (100)

Figures in parentheses indicate percentage to total.

Table 4. Post-harvest losses in Nendran at transporter level

Sl. No.	Factors responsible for losses	Average quantity handled (tonnes)	Average quantity loss (tonnes)	Percentage loss (%)
1.	Mechanical and physical damage	424	1.8	0.42 (10)
2.	Pest and disease incidence	424	1.6	0.38 (8)
3.	Poor packaging	424	2	0.42 (11)
4.	Lack of cold-chain infrastructure	424	1.4	0.33 (7)
5.	Transport and handling constraints	424	11.3	2.67 (61)
6.	Market-related delays	424	0.5	0.12 (3)
Percentage loss at transporter level (%)				4.39 (100)

Figures in parentheses indicate percentage to total.

Table 5. Post-harvest losses in Nendran at retailer level

Sl. No.	Factors responsible for losses	Average quantity handled (tonnes)	Average quantity loss (tonnes)	Percentage loss (%)
1.	Mechanical and physical damage	3.55	0.15	4.23 (27)
2.	Pest and disease incidence	3.55	0.09	2.54 (16)
3.	Poor packaging	3.55	0.11	3.10 (20)
4.	Lack of cold-chain infrastructure	3.55	0.07	1.97 (13)
5.	Transport and handling constraints	3.55	0.09	2.54 (16)
6.	Market-related delays	3.55	0.04	1.13 (8)
Percentage loss at retailer level (%)				15.51 (100)

Figures in parentheses indicate percentage to total.

level. Delayed sales and poor storage conditions often lead to over-ripening, which significantly reduces the marketable quality of produce (40, 41). This indicates the losses at this stage depend more on turnover speed and storage conditions than on production factors.

Earlier studies also reported high retail losses. About 64.10 % of total banana losses occurred at retail due to rotting and handling damage (35), while another study reported 56 % losses at this stage (31). Retail loss of 16.6 % in conventional markets was close to the present estimate, whereas cooperative marketing recorded only 8.72 % (17). Lower losses of 7.5 % were observed with faster turnover (36) and 14.41 % losses were reported in Sri Lanka (30). Thus, retail losses mainly result from repeated handling and longer holding time. Faster sales, simple cooling and improved packaging can reduce deterioration and protect trader income.

Total losses along the supply chain

The incidence of losses at different stages is illustrated in Fig. 2 and 3. Fig. 4 shows the proportional contribution of different supply chain stages to the total losses in the Nendran banana supply chain. The results reveal a total loss of 42.11 %, which is contributed by both pre-harvest and post-harvest stages. The pre-harvest losses at the field level were estimated at 10.11 %, mainly due to weather shocks, pest and disease and management constraints. Comparable levels of pre-harvest losses have been reported in Sub-Saharan Africa, where losses in banana and plantain ranged from 20.7 to 100 % suggest that climatic and biological risks remain the basic source of yield reduction (19). The post-harvest losses are higher in the downstream stages, mainly at the retailer level (15.51 %), followed by wholesaler level (8.56 %), while transporter (4.39 %) and field post-harvest (3.54 %) losses were comparatively lower. This pattern indicates that deterioration increases as handling frequency and holding time increase along the marketing chain.

Comparable studies also show larger losses beyond the farm gate. Around 20 % between farm and retail in Sri Lanka (19) and 26.5–45.78 % total post-harvest loss in Ethiopia (20, 31, 42). In

contrast, lower losses of 15.43 % in Gujarat were linked to shorter channels and better handling (18). Therefore, the results suggest that production risks explain only part of the problem, while marketing structure plays a major role in total loss. Reducing intermediaries, improving handling and speeding up movement of produce can significantly lower overall losses.

Determinants of pre- and post-harvest losses

The regression model exhibited strong explanatory power with an R^2 value of 0.86, indicating that 86 % of the variation in Nendran losses is explained by the variables included in the model, as reported in Table 6. Since the dependent variable is specified in logarithmic form, the estimated coefficients for non-logarithmic independent variables are interpreted as semi-elasticities, indicating percentage change in losses. The regression results show that climate shock increases losses by about 14.5 %, while pest incidence raises losses by nearly 9.9 % confirming that natural and biological stresses remain the primary risk factors. Better packaging reduces losses by around 8.7 %. Experience also plays a role, as each additional year reduces losses by approximately 0.7 %. The negative elasticity of scale indicates that a 1 % increase in scale of operation reduces losses by 0.815 %, suggesting the presence of economies of scale.

Taking farm pre-harvest as the reference category, the dummy coefficients indicate significant differences across stages. Losses at the farm post-harvest, wholesaler and transporter stages are significantly higher than the reference category as well as other stages. This supports the earlier findings that the retail level is the most loss-prone segment due to repeated handling, longer display periods and limited cold storage facilities. Similar studies have shown that mechanical injury, poor transport, pest and disease, experience and inadequate storage significantly determine losses (42–45). In summary, losses mainly increase due to environmental and biological stress, while management capacity reduces them. Therefore, risk-reduction at farm level and handling improvements in later stages (especially retail) are both essential for improving overall supply chain efficiency.

Table 6. Results of multiple linear regression (Banana losses across supply chain)

Variables	Coefficients	Standard error	t-value
Intercept	4.890***	0.143	34.107
Climate shock	0.145***	0.044	3.286
Pest incidence	0.099**	0.048	2.082
Packaging quality	-0.087**	0.039	-2.224
Ln_distance	0.016	0.040	0.476
Experience	-0.007***	0.002	-2.881
Ln_scale	-0.815***	0.022	-36.490
D_Farm post	-0.864***	0.045	-19.317
D_Wholesaler	-0.939***	0.094	-10.001
D_Retailer	1.378***	0.176	7.805
D_Transporter	-1.349***	0.091	-14.801

R^2 : 0.86; **, *** denote 5 % and 1 % level of significance.

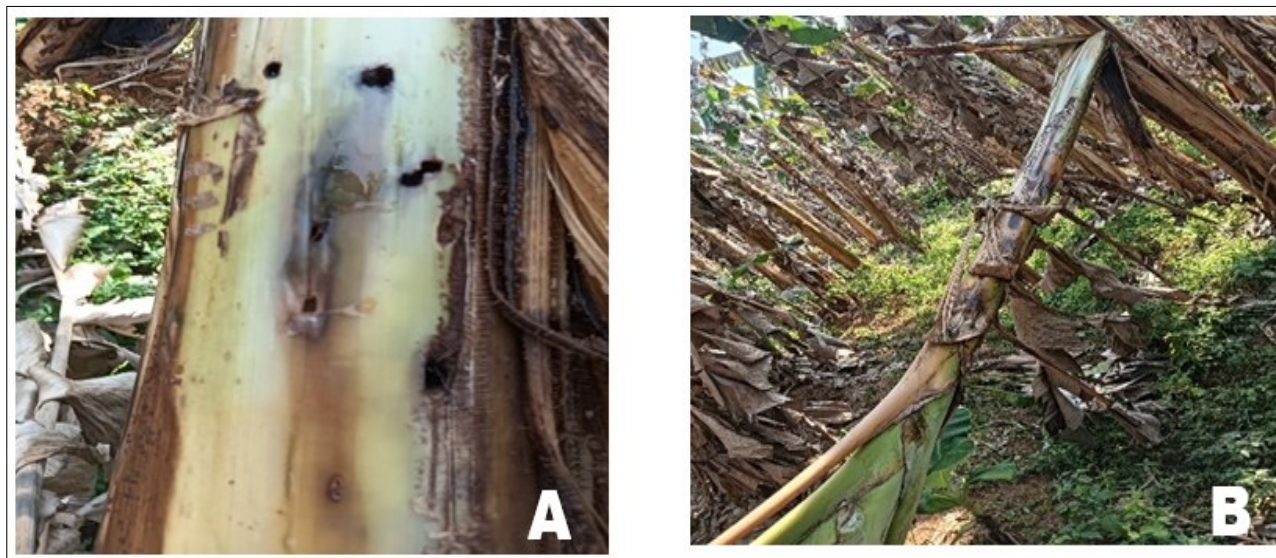


Fig. 2. Field-level pre-harvest losses in Nendran banana. (A) Pest infestation; (B) Wind damage.



Fig. 3. Post-harvest losses in Nendran banana. (A) Mechanical damage; (B) Lack of cold storage.

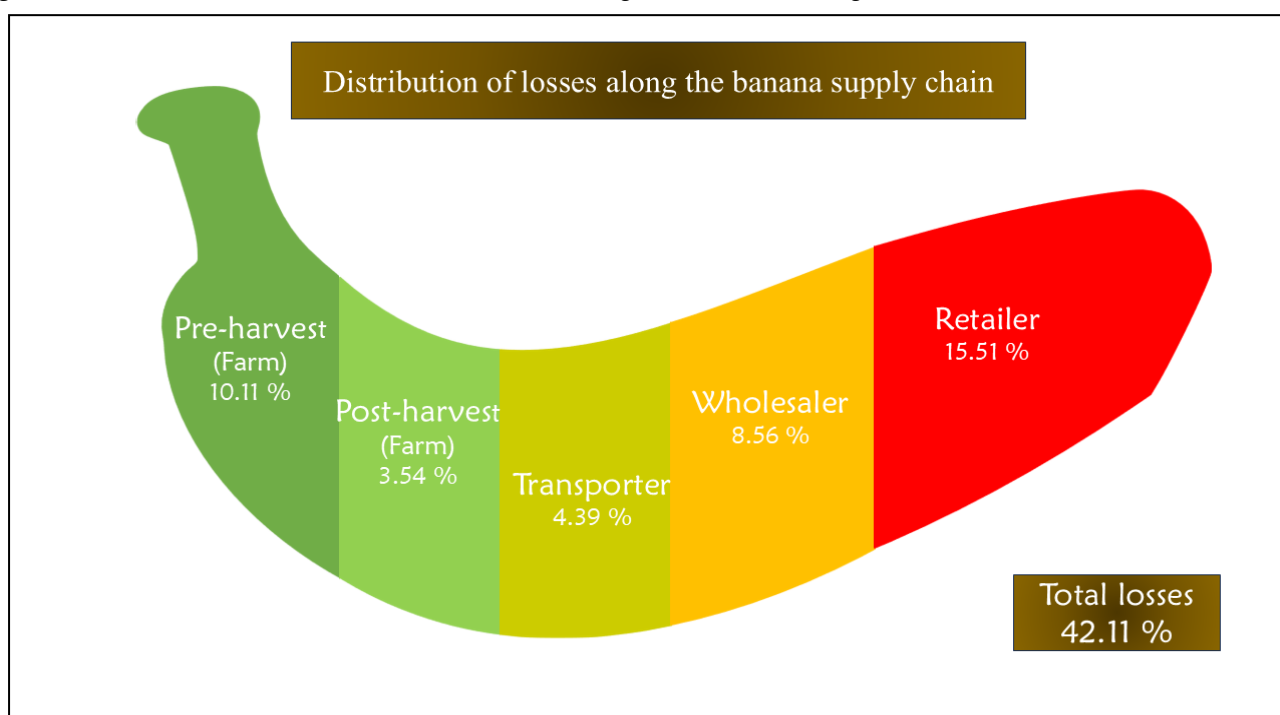


Fig. 4. Stage-wise distribution of cumulative pre- and post-harvest losses in Nendran banana.

Challenges faced by intermediaries in the Nendran supply chain

Garrett ranking showed that price volatility was the most serious problem with a score of 72.35 (Fig. 5). Frequent supply and demand changes reduce margins and sudden price falls cause losses when produce cannot be sold quickly. Market glut and delayed sales ranked second (68.22), where excess arrivals increase holding time and spoilage. Climatic damage ranked third (55.72), affecting produce during handling and transport. Poor quality produce from farms (53.28) led to price discounts, showing that upstream practices directly affect intermediary returns. High transport cost (46.30) and lack of storage (46.22) further reduced credit/payment delay (34.90) and grading variability (33.35).

Earlier studies also reported similar constraints such as price fluctuation, weak storage facilities, transport problems and credit limitations (46, 47). Together, these results indicate that intermediaries mainly face market and infrastructure risks rather than production risks. Improving storage, market information and coordination with farmers can reduce spoilage and stabilise returns across the supply chain.

Conclusion

The study shows that losses in the Nendran banana supply chain accumulate from production to retail rather than occurring at a single stage. The estimated loss of 42.11 % indicates substantial inefficiency in moving produce from farm to consumer. Pre-harvest losses are mainly linked to climatic shocks and pest incidence while post-harvest losses increase downstream and are highest at the retail stage due to repeated handling, longer holding periods and absence of cold-chain support. Regression results show that biological risks increase the losses, whereas better packaging, experience and larger operational scale help reduce them.

These patterns indicate a systemic problem, where early damage weakens fruit quality and later spoilage is intensified by

delayed sales and price fluctuations. Therefore, loss reduction requires systemic improvements across stages. At the farm level, climate-resilient cultivation, proper plant protection and quality planting material can limit initial damage. Training in proper harvesting and basic handling practices can reduce bruising, while the use of ventilated crates and cushioning during loading and transport can prevent mechanical injury. Simple pack houses, short-term cooling and regulated ripening facilities can slow deterioration during transit and marketing. Improved market information, aggregation and organised marketing arrangements can shorten selling time and reduce distress disposal. Future research may focus on quantifying the economic feasibility of cold-chain investments, evaluating digital market integration for reducing marketing delays and assessing the role of institutional innovations such as farmer producer organisations in improving supply chain efficiency.

Acknowledgements

The authors gratefully acknowledge the support and facilities provided by Kerala Agricultural University for this research.

Authors' contributions

MN executed the research work, designed the methodology and drafted the initial manuscript. CP supervised the entire research work. PA and SP assisted in data analysis. DJM and SKN critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

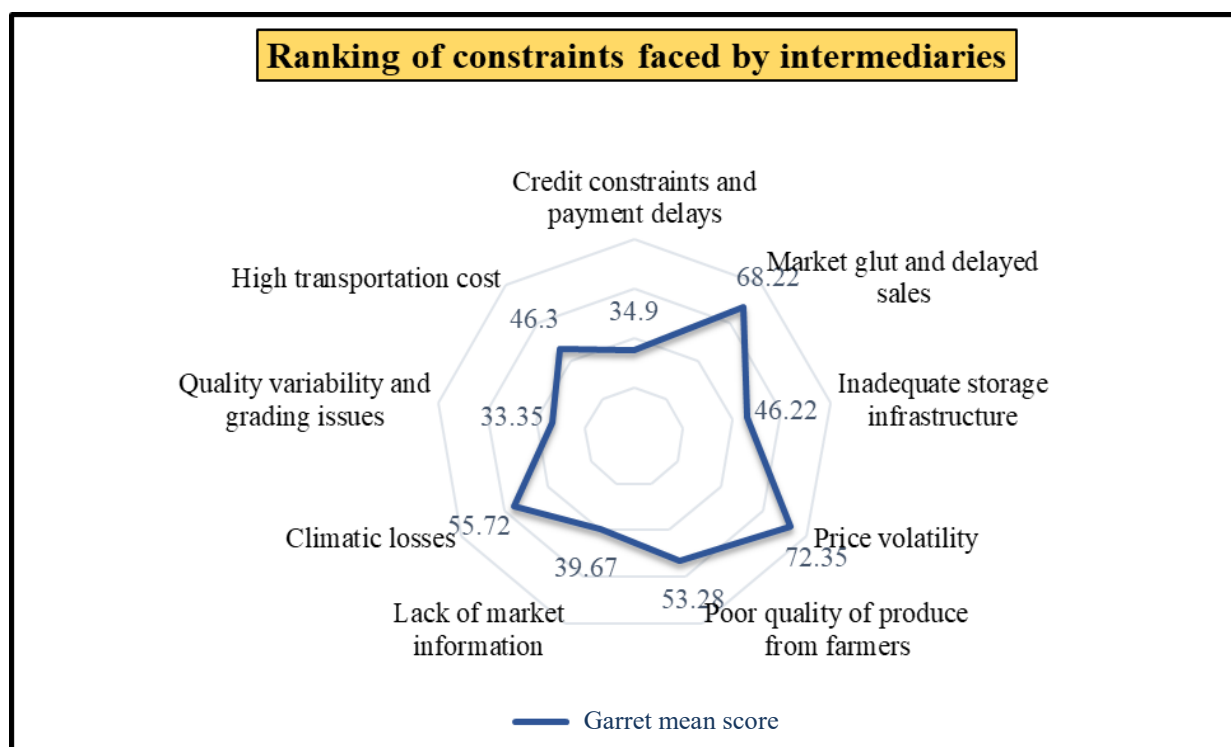


Fig. 5. Severity of constraints faced by intermediaries in the Nendran banana supply chain.

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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