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Constraints Faced by Walnut Growers and Strategies for Sustainable Development of Walnut Enterprise in Kupwara District, J&K, India

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Abstract

Despite the high economic potential of walnut (*Juglans regia* L.) cultivation in Jammu and Kashmir, India with J&K contributing ~98% of national walnut exports the sector confronts a range of structural, institutional, and technical constraints that impede productivity, profitability, and enterprise expansion. This paper presents a systematic analysis of constraints faced by 110 walnut growers in Kupwara district, the leading walnut-producing district of North Kashmir, selected by proportionate allocation sampling from 27 villages across 9 horticultural zones. Data were collected through personal interviews using a structured interview schedule. Results reveal that irregular and unplanned orchard layout (97.27%) and non-availability of dehulling machines (94.54%) are the most widespread constraints, followed by lack of quality planting material (88.18%), poor awareness of high-density walnut production (78.18%), and price fluctuations/distress sales (77.27%). Poor marketing facilities (72.27%), inadequate financial and technical support from the horticulture department (70.90%), hard-shell nut types (45.45%), bird damage (30.00%), and harvesting risk (13.63%) were also documented. Constraints were categorized into five thematic clusters: infrastructure, market, technical/knowledge, policy/institutional, and biotic/abiotic factors. Evidence-based, multi-level intervention strategies are proposed to address each constraint cluster and unlock the sector's demonstrated economic potential.

***Key words*:** Walnut cultivation, Production constraints, High-density orchard, Post-harvest infrastructure, Market constraints, Extension services

Walnut (*Juglans regia* L.) is one of the most important temperate nut crops cultivated worldwide due to its high nutritional value, economic significance, and increasing demand in domestic and international markets. India is among the leading walnut-producing countries, with the Union Territory of Jammu and Kashmir contributing nearly 98% of the country's total walnut production and exports. According to APEDA [1] and the Directorate of Horticulture, Kashmir [2], Jammu and Kashmir has approximately 85,622 ha under walnut cultivation with an annual production of about 275,449 MT, generating export earnings of nearly Rs. 66.75 crores. Kashmiri walnuts are internationally recognized for their superior quality, characterized by thin shells, light kernel colour, and shelling percentage exceeding 50%, enabling them to command premium prices in comparison with walnuts from many other producing regions, including California [3-4]. Despite these inherent advantages, walnut productivity in the region remains considerably below its potential. The average productivity of about 2.71 MT/ha is substantially lower than the attainable yield of nearly 4.5 MT/ha under improved production practices, indicating a wide productivity gap that limits farmers' income and the overall competitiveness of the sector. Several studies have attributed this productivity gap to a combination of production, infrastructural, institutional, and marketing constraints. Shukla and Pandey [3] reported that the lack of certified quality planting material, prolonged juvenile period, and inadequate orchard management practices are among the major production constraints affecting walnut cultivation in India. Similarly, Qammer and Baba [5] observed that walnut value chains in Jammu and Kashmir are characterized by fragmented marketing systems, inadequate processing and storage facilities, and substantial post-harvest losses arising from poor dehulling, grading, packaging, and transportation infrastructure. Studies on other nut crops have also highlighted similar challenges. Babalola [6] reported that marketing intermediaries captured a major share of consumer prices in African walnut markets, reducing producers' profitability. Badhe and Tambati [7], Hatai [8], Kidunda *et al.* [9], and Raykerl *et al.* [10] identified poor market access, inadequate extension support, limited availability of quality planting material, weak adoption of improved production technologies, and price fluctuations as major constraints affecting arecanut and cashewnut cultivation. Wasula *et al.* [11] emphasized that favourable farmer perceptions alone are insufficient for technology adoption when institutional and market-related constraints persist. Sajeev and Saroj [12] further demonstrated

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that farmers' exposure to information sources and extension networks significantly influences the adoption of improved technologies in perennial horticultural crops.

Kupwara district, one of the leading walnut-producing districts of North Kashmir, possesses favourable agro-climatic conditions for walnut cultivation and has established market linkages through local traders and exporters. However, walnut cultivation in the district is predominantly traditional, with trees scattered along field bunds, hill slopes, and wastelands rather than being maintained as scientifically managed orchards. In addition, inadequate post-harvest infrastructure, limited access to quality planting material, insufficient extension support, poor processing and grading facilities, and unstable market prices continue to restrict productivity and profitability. Although previous studies have documented several production and marketing constraints in walnut and other tree nut crops, location-specific empirical evidence for Kupwara district remains limited. A systematic assessment of the constraints faced by walnut growers is therefore essential for developing appropriate technological, institutional, and policy interventions aimed at enhancing productivity, improving market efficiency, and increasing farm income. Keeping this in view, the present study was undertaken to identify and analyse the major constraints encountered by walnut growers in Kupwara district of Jammu and Kashmir.

MATERIALS AND METHODS

The present investigation was carried out in Kupwara district of Jammu and Kashmir, one of the major walnut-producing districts of North Kashmir. The study forms part of a comprehensive research programme designed to assess the socio-economic characteristics, production practices, and constraints associated with walnut cultivation in the district. A descriptive research design was adopted as the study primarily aimed to identify and analyse the constraints encountered by walnut growers in production, post-harvest handling, and marketing. The study was conducted using primary data collected from walnut growers through a field survey. A multistage sampling technique was employed for the selection of respondents. Nine horticultural zones of Kupwara district were included in the study, from which 27 walnut-growing villages were selected based on the extent of walnut cultivation. From these villages, a total of 110 walnut growers were selected as respondents. The sampling procedure and respondent selection methodology are described in detail in the companion papers of this research series. The selected respondents represented different farm-size categories and varying levels of farming experience, thereby ensuring adequate representation of the walnut-growing community in the study area. Primary data were collected through personal interviews using a pre-tested and structured interview schedule developed in consultation with experts in agricultural extension, horticulture, and agricultural economics. The interview schedule consisted of both closed- and open-ended questions covering production, post-harvest management, marketing, institutional support, and the constraints experienced by walnut growers. Before the final survey, the schedule was pre-tested with a small group of walnut growers outside the selected sample area to ensure clarity, relevance, and reliability of the questions. Necessary modifications were incorporated based on the feedback obtained during pre-testing.

To identify the constraints affecting walnut cultivation, respondents were provided with a comprehensive checklist of potential constraints compiled from an extensive review of literature, expert consultations, and preliminary field observations. The checklist included production, infrastructural, marketing, institutional, technological, and environmental constraints commonly reported in walnut and other tree nut production systems. Each respondent was asked to indicate the constraints that they had personally experienced during walnut cultivation and marketing. Multiple responses were permitted, as growers generally encounter more than one constraint simultaneously. Consequently, the total frequency exceeded the number of respondents. The collected data were scrutinized, coded, classified, and tabulated for statistical analysis. Descriptive statistical tools, including frequency counts and percentages, were employed to quantify the prevalence of each constraint among the respondents. The identified constraints were ranked in descending order according to the percentage of respondents reporting each constraint, with the highest percentage assigned the first rank. For better interpretation and discussion, the individual constraints were further grouped into five major thematic categories: (i) infrastructure constraints, (ii) market and pricing constraints, (iii) technical and knowledge-related constraints, (iv) institutional and policy-related constraints, and (v) biotic and abiotic constraints. This thematic classification facilitated a comprehensive understanding of the major problem areas affecting walnut production and marketing and helped identify priority interventions required for improving the walnut production system in the study area. The results obtained from the analysis were interpreted in light of the existing literature on walnut and other perennial horticultural crops to identify common patterns and location-specific issues. The findings are expected to provide useful inputs for researchers, extension agencies, policymakers, and horticultural development departments in formulating strategies to enhance walnut productivity, strengthen market linkages, and improve the livelihoods of walnut growers in Jammu and Kashmir.

RESULTS AND DISCUSSION

Comprehensive constraint profile

Table 1 Constraints faced by walnut growers in Kupwara district, ranked by frequency (N = 110)

Rank	Constraint	Frequency	Percent	Constraint category
1	Irregular/unplanned orchard layout	107	97.27	Infrastructure
2	Non-availability of dehulling machines	104	94.54	Infrastructure
3	Lack of good quality planting material	97	88.18	Technical
4	Lack of awareness on high-density walnut production	86	78.18	Knowledge
5	Price fluctuations and distress sales	85	77.27	Market
6	Poor marketing facilities	80	72.27	Market
7	Inadequate financial and technical support from horticulture department	78	70.90	Institutional
8	Hard-shell nut types (poor shelling percentage)	50	45.45	Technical
9	Bird damage to nuts	33	30.00	Biotic
10	Risk in harvesting (height of trees, terrain)	15	13.63	Abiotic/Physical

Infrastructure constraints

Irregular and unplanned orchard layout (97.27%)

The near-universal constraint of irregular orchard layout is the most fundamental structural problem in Kupwara's walnut sector. The historical pattern of planting walnut trees opportunistically on bunds, hillsides, terraces, and wastelands wherever space was available rather than where agronomy dictated has resulted in orchards that are unmanageable by any modern standard. Trees are planted at irregular spacings (ranging from 5 to over 30 metres apart), on slopes that prevent mechanization, on bunds too narrow for any equipment access, and on soils that were never assessed for suitability. The consequences of this planning failure cascade through every aspect of cultivation: fertilizer application is impractical (trees are not in rows), pruning is difficult or dangerous, harvest requires long ladders on uneven terrain, and inter-row crop management is impossible. Moreover, these trees cannot be retrofitted into planned orchards the only solution is gradual replacement with scientifically established high-density orchards, which requires long-term planning, financing, and a 10-15 years transition during which old trees continue producing while new orchards reach bearing age. This constraint is consistent with Qammer and Baba's [5] observations on the capital-intensive nature of walnut production system transformation.

Non-availability of dehulling machines (94.54%)

Walnut dehulling the removal of the green outer husk from the hard shell is the most critical post-harvest operation, determining both the quality (staining of shell from hull tannins) and efficiency of processing. In Kupwara, 94.54% of respondents reported complete non-availability of mechanical dehulling equipment. This forces manual dehulling using hands or crude tools, resulting in: (a) significant hand-staining and chemical burn from hull tannins; (b) slow processing rates that create bottlenecks during the concentrated harvest period; (c) inconsistent quality as over-ripe hulls stain the shell brown; and (d) high labour costs. Mechanical dehullers (capacity: 500–2,000 kg/hour) are commercially available and used extensively in California walnut production, enabling rapid processing with consistent quality. Their absence in Kupwara represents a critical infrastructure gap. The capital cost of a community dehuller (approximately Rs. 3-5 lakh for a medium-capacity machine) is prohibitive for individual smallholders but entirely feasible for cooperative groups or FPOs. Qammer and Baba [5] specifically highlighted dehulling infrastructure as a key value chain constraint in J&K walnut, and the present study 15 years later confirms the problem persists. Government investment in community processing centres, potentially through schemes like PMKSY or MIDH, could address this bottleneck at scale.

Technical constraints

Lack of good quality planting material (88.18%)

The unavailability of certified quality planting material is a constraint with uniquely long-term implications. Unlike annual crops where suboptimal seed affects one season, a poorly selected walnut seedling or grafted plant establishes a tree that occupies land for 50-100 years. The dominance of seedling-propagated trees with their inherent genetic heterogeneity, long juvenile periods (8–15 years), and unpredictable quality attributes directly results from the absence of accessible, affordable grafted planting material with proven performance characteristics. SKUAST-K has developed and identified superior walnut genotypes with improved shelling percentage, earlier bearing, and better adaptability to different elevations of the Kashmir Valley. However, these are not available at scale to farmers in Kupwara. The few government nurseries that exist produce limited quantities of vegetatively propagated material, and private sector nursery development for walnut is nascent. The result is that the majority of new plantings by farmers even those motivated to establish systematic orchards default to seed-propagated material, perpetuating the quality and productivity disadvantages of the current planting stock. This finding aligns with Shukla and Pandey [3], who identified quality planting material scarcity as one of the two most critical constraints in India's walnut industry.

Hard-shell nut types (45.45%)

Approximately 45.45% of respondents reported that their trees produce hard-shelled nuts with low shelling percentage (typically <40%), significantly reducing consumer acceptance and market value. Kashmiri walnut is globally prized when it achieves >50% shelling percentage with paper-thin shells quality attributes that depend entirely on the genetic characteristics of the planting material. Hard-shell types, typically arising from seedling propagation using genetically inferior seed, produce nuts that are difficult to crack and have lower kernel recovery. This directly reduces farmgate price, as traders discount heavily for hard-shell lots. The constraint is inseparable from the planting material problem: addressing both simultaneously through a coordinated quality planting material programme would yield multiplicative benefits.

Market and pricing constraints

Price fluctuations and distress sales (77.27%)

Price volatility and distress selling are closely interrelated market failures that affect 77.27% of walnut growers in Kupwara. The walnut harvest in J&K is highly concentrated over 80% of production occurs within a 4-6 weeks window in September-October creating a sudden surge in supply that exceeds local processing and storage capacity. Traders, aware of this temporal supply concentration, collude to depress farmgate prices during peak harvest, forcing farmers who lack storage infrastructure to sell immediately at distressed prices. Babalola [6] documented the identical dynamic for African walnut in Nigeria, where village merchants exploited farmers' lack of post-harvest infrastructure and market alternatives. The establishment of Minimum Support Price (MSP) mechanisms, walnut-specific cold storage and dry storage facilities, and Farmer Producer Organizations (FPOs) that enable collective bargaining are the three complementary interventions needed to address this constraint. FPOs could accumulate walnut stocks during harvest and release them to markets over a longer period, smoothing price fluctuations and eliminating distress sales. Hatai [8] recommended cooperative marketing structures specifically to address similar price volatility problems in cashewnut a directly applicable model for walnut in J&K.

Poor marketing facilities (72.27%)

The infrastructure of walnut marketing in Kupwara is rudimentary. Primary marketing occurs through village-level commission agents and traders who buy at farm gate during harvest, with no market yard facilities, grading infrastructure, or price discovery mechanisms available to farmers. There are no formal auctions, no regulated market yards (mandis) specifically for walnut, and no electronic market linkages. Farmers have no access to real-time price information from distant markets (Delhi, Mumbai, international export markets) that would enable them to compare prices or identify better buyers. The absence of cold storage means that no form of price

arbitrage holding produce until prices improve is possible. The development of Walnut Marketing Complexes at strategic locations in Kupwara district incorporating grading facilities, mechanical processing equipment, dry storage, and digital price information boards would transform the marketing environment. Such complexes could be developed under the National Horticulture Mission (NHM) or Mission for Integrated Development of Horticulture (MIDH) with FPO management models. Qammer and Baba [5] specifically recommended value chain modernization investments in J&K walnut processing and marketing as the highest-return development intervention.

Institutional and policy constraints

Inadequate financial and technical support (70.90%)

Seven out of ten walnut growers (70.90%) reported inadequate financial and technical support from the Department of Horticulture and allied government agencies. This finding, read alongside the 82.73% low extension contact and 69.01% no-training figures from the socio-economic analysis, paints a consistent picture of institutional under-investment in the walnut sector. The government's resource allocation to walnut appears substantially below what the crop's contribution to J&K's economy and export revenue would justify. Multiple schemes exist on paper NHM, MIDH, PMFBY (crop insurance) but their reach to walnut growers in Kupwara appears limited. Several specific institutional failures were identified: (a) extension worker-to-farmer ratios in Kupwara are inadequate, with too few horticultural development officers to provide meaningful crop-specific technical guidance; (b) financial support schemes for walnut orchard establishment require complex documentation and multi-year approvals that are inaccessible to semi-literate smallholders; (c) no crop-specific insurance scheme exists for walnut, exposing growers to catastrophic loss risk from frost, hailstorm, or bird damage. Sajeev and Saroj [12], studying cashewnut in Kerala, found that cosmopoliteness (institutional connectivity) was the strongest predictor of technology adoption reinforcing the case for rebuilding the institutional interface between government and walnut farmers in Kupwara.

Biotic and abiotic constraints

Bird damage (30.00%)

Bird damage to walnut, reported by 30.00% of respondents, is an increasingly significant biotic constraint as orchards mature and nut density increases. Various corvid species (crows, ravens) and parakeets are known to damage walnut nuts before and during harvest, reducing marketable yield. The extent of bird damage is exacerbated by the unmanaged, scattered nature of walnut trees on bunds and hillsides, which prevents effective bird-scaring operations. In planned, high-density orchards, net-based or sound-deterrent bird protection systems could be economically applied, but these are impractical for unplanned scattered trees.

Risk in harvesting (13.63%)

Harvesting walnut from tall trees (often 15-20 metres in unmanaged old trees) on steep hillside terrains poses significant physical risk. The 13.63% constraint prevalence reflects genuine occupational safety hazards that result in injuries annually. While relatively low in comparison to other constraints, harvesting risk has a chilling effect on farmer motivation to invest in orchard management: why invest heavily in a tree that may injure harvesters? The shift to high-density orchard systems with shorter, controlled tree sizes (through appropriate rootstock and pruning management) would substantially reduce harvesting risk yet another argument for orchard modernization.

Table 2 Thematic grouping of constraints by category with aggregate impact assessment

Category	Key constraints	Average prevalence (%)	Priority level
Infrastructure	Irregular orchard layout (97.27%), No dehulling machines (94.54%)	95.91	Critical
Technical	Poor planting material (88.18%), Hard-shell nuts (45.45%)	66.82	High
Knowledge	Lack of awareness on HD walnut (78.18%)	78.18	High
Market	Price fluctuations (77.27%), Poor marketing (72.27%)	74.77	High
Institutional	Inadequate financial/technical support (70.90%)	70.90	High
Biotic/Physical	Bird damage (30.00%), Harvesting risk (13.63%)	21.82	Moderate

Thematic constraint cluster analysis

The thematic classification of the constraints encountered by walnut growers in Kupwara district provides a comprehensive understanding of the relative severity of different problem areas affecting walnut cultivation and marketing (Table 2). The analysis revealed that infrastructure-related constraints emerged as the most critical category, recording the highest average prevalence of 95.91 per cent. This category comprised irregular orchard layout (97.27%) and the absence of dehulling machines (94.54%), indicating that inadequate physical infrastructure is the foremost impediment to efficient walnut production in the study area. The predominance of scattered walnut trees on field bunds, hill slopes, and wastelands restricts the adoption of scientific orchard management practices, mechanization, and efficient harvesting. Simultaneously, the lack of dehulling and primary processing facilities compels growers to depend on traditional post-harvest methods, resulting in higher labour costs, increased post-harvest losses, reduced kernel quality, and lower market value. These findings corroborate the observations of Qammer and Baba [5], who reported inadequate processing infrastructure as one of the principal bottlenecks in the walnut value chain of Jammu and Kashmir.

Among the remaining categories, knowledge-related constraints recorded a high average prevalence of 78.18 per cent, primarily due to the lack of awareness regarding high-density walnut plantations and improved orchard management technologies. This finding suggests that extension services and technology dissemination remain inadequate despite the economic importance of walnut cultivation in the region. Market-related constraints ranked next with an average prevalence of 74.77 per cent, mainly attributed to frequent price fluctuations (77.27%) and poor marketing infrastructure (72.27%). These constraints reduce farmers' bargaining power, create uncertainty in income realization, and often compel growers to dispose of their produce through intermediaries at lower prices. Similar observations have been reported by Babalola [6] and Hatai [8], who highlighted weak marketing systems, price instability, and dependence on middlemen as major limitations affecting profitability in nut crop production.

Likewise, institutional constraints recorded a high prevalence of 70.90 per cent, indicating inadequate access to financial assistance, technical guidance, and government support programmes. Limited institutional interventions hinder farmers' ability to adopt improved technologies, establish scientific orchards, and invest in post-harvest infrastructure. Comparable findings were reported by Kidunda *et al.* [9], who emphasized that inadequate extension support significantly constrains technology adoption among tree crop growers.

The technical constraints category registered an average prevalence of 66.82 per cent, reflecting the widespread problem of poor-quality planting material (88.18%) and the occurrence of hard-shell nuts (45.45%). The limited availability of certified planting material restricts the establishment of high-yielding orchards and contributes to poor productivity, while hard-shell nuts adversely affect consumer preference and market price. These findings are consistent with those of Shukla and Pandey [3], who identified poor planting material as one of the most significant production constraints in walnut cultivation. In contrast, biotic and physical constraints were comparatively less severe, with an average prevalence of 21.82 per cent, comprising bird damage (30.00%) and harvesting risks associated with tall trees (13.63%). Although these constraints affected fewer respondents, they still contributed to yield losses and increased harvesting costs in specific locations. Overall, the thematic analysis clearly demonstrates that infrastructure deficiencies, inadequate knowledge dissemination, weak market systems, and insufficient institutional support constitute the principal barriers to the sustainable development of walnut cultivation in Kupwara district. The findings underscore the need for integrated interventions focusing on scientific orchard establishment, improved processing infrastructure, quality planting material, strengthened extension services, efficient marketing systems, and enhanced institutional support to improve productivity, profitability, and the long-term competitiveness of the walnut sector [13].

Table 3 Integrated solutions framework for walnut constraints in Kupwara district

Constraint	Proposed intervention	Implementing agency	Timeline
Irregular orchards	High-density orchard establishment programme; land consolidation schemes for compact plantings	Dept. Horticulture, SKUAST-K	Medium-term (3-5 yrs)
No dehulling machines	Community dehuller installation (1 per zone); FPO-managed processing centres	Dept. Horticulture, MIDH	Short-term (1-2 yrs)
Poor planting material	SKUAST-K certified grafted sapling nurseries in each zone; quality planting material subsidy	SKUAST-K, Private sector	Short-term (1-2 yrs)
Awareness gap	Mass training campaigns; demonstration orchards; FFS on HD walnut	KVK, Dept. Horticulture, SKUAST-K	Immediate (0-1 yr)
Price fluctuations	MSP for walnut; FPO-based collective marketing; e-NAM linkage	Department of Horticulture, NHM	Short-term (1-2 yrs)
Poor marketing	Walnut Marketing Complex (grading, storage, digital prices) per zone	MIDH, State Govt.	Medium-term (2-3 yrs)
Institutional support gap	Dedicated walnut extension officer per block; simplified scheme documentation	Dept. Horticulture	Immediate (0-1 yr) (0-2
Hard-shell types	Accelerated replacement of hard-shell trees with certified soft-shell varieties	SKUAST-K, NHM	Long-term (5-10 yrs)

Integrated solutions framework

The integrated solutions framework developed for walnut cultivation in Kupwara district provides a strategic roadmap for addressing the production, marketing, institutional, and infrastructural constraints identified during the study (Table 3). The proposed interventions are prioritized according to the nature and severity of the constraints and are linked with appropriate implementing agencies and realistic timelines, thereby facilitating coordinated action among research institutions, extension agencies, and government departments. Infrastructure-related interventions were accorded the highest priority owing to the critical nature of these constraints. The establishment of scientifically managed high-density walnut orchards through orchard redevelopment programmes and land consolidation initiatives has been proposed as a medium-term strategy to overcome the widespread problem of irregular orchard layouts [14]. Scientific orchard establishment would facilitate improved canopy management, efficient irrigation and nutrient application, mechanized operations, and higher productivity per unit area. Similarly, the installation of community-based dehulling machines and farmer producer organization (FPO)-managed processing centres in each horticultural zone has been recommended as a short-term intervention to minimize post-harvest losses, improve kernel quality, reduce labour requirements, and enhance value addition. Such decentralized processing infrastructure would enable small and marginal growers to access modern post-harvest facilities without incurring substantial individual investment, thereby improving market competitiveness. To address technical and knowledge-related constraints, the framework emphasizes the establishment of certified grafted walnut nurseries by SKUAST-Kashmir and private entrepreneurs with financial support under relevant horticultural development programmes. The availability of quality planting material is expected to improve orchard productivity, ensure varietal uniformity, and accelerate the

replacement of senile and low-yielding trees. In addition, the proposed large-scale awareness campaigns, establishment of demonstration orchards, Farmer Field Schools (FFS), and regular capacity-building programmes by Krishi Vigyan Kendras (KVKs), the Department of Horticulture, and SKUAST-Kashmir are expected to enhance farmers' knowledge regarding high-density planting systems, improved orchard management practices, integrated nutrient management, pest and disease management, and scientific harvesting techniques. Similar extension-oriented approaches have been widely recognized as effective strategies for improving technology adoption and productivity in perennial horticultural crops [15].

The proposed market-oriented interventions focus on reducing income instability and strengthening farmers' bargaining power. The introduction of a minimum support price (MSP) mechanism, promotion of collective marketing through Farmer Producer Organizations, and integration of walnut marketing with electronic marketing platforms such as the National Agriculture Market (e-NAM) are expected to reduce the adverse effects of price fluctuations and improve price realization. Furthermore, the establishment of Walnut Marketing Complexes equipped with grading, storage, packaging, and digital market information facilities would improve transparency in price discovery, reduce the role of intermediaries, and facilitate direct market access for growers [16]. These interventions are expected to enhance value addition and improve the overall efficiency of the walnut supply chain.

Institutional strengthening forms another key component of the proposed framework. The appointment of dedicated walnut extension officers at the block level and simplification of procedures for accessing government schemes would improve the delivery of technical advisory services and increase farmers' participation in developmental programmes. Improved coordination among research organizations, extension agencies, financial institutions, and line departments would facilitate timely dissemination of technologies and greater adoption of scientific production practices. In the long term, the gradual replacement of hard-shell walnut trees with certified soft-shell, high-yielding cultivars through systematic orchard rejuvenation programmes is expected to improve kernel quality, market acceptability, and export competitiveness. The integrated solutions framework highlights that sustainable development of the walnut sector in Kupwara district requires simultaneous investments in infrastructure, quality planting material, extension services, institutional support, and market reforms. The coordinated implementation of these interventions has the potential to substantially improve productivity, reduce post-harvest losses, strengthen farmers' incomes, and enhance the competitiveness of the walnut industry in Jammu and Kashmir.

CONCLUSION

The present study provides a comprehensive empirical assessment of the constraints affecting walnut cultivation in Kupwara district of Jammu and Kashmir and demonstrates that the productivity and profitability of the walnut enterprise are constrained by a complex interaction of infrastructural, technical, knowledge, market, and institutional factors. The predominance of irregular orchard layout (97.27%) and the absence of mechanical dehulling facilities (94.54%) highlights the urgent need for modernization of orchard systems and post-harvest infrastructure, while the widespread shortage of certified quality planting material (88.18%) and limited awareness of high-density walnut production (78.18%) continue to impede technological advancement and long-term productivity. Furthermore, market imperfections, reflected in price fluctuations (77.27%) and inadequate marketing facilities (72.27%), together with insufficient financial and technical support from extension agencies (70.90%), significantly restrict farmers' capacity to adopt improved production practices and realize better economic returns. These findings confirm that the identified constraints are interrelated and therefore require an integrated rather than fragmented development approach. Accordingly, priority should be given to establishing community-based dehulling and processing centres, promoting scientifically managed high-density orchards through the supply of certified grafted planting material, strengthening extension services through regular training and demonstration programmes, developing Farmer Producer Organizations and modern marketing infrastructure, integrating walnut marketing with digital platforms, and implementing dedicated policy support for orchard modernization and value-chain development. The coordinated implementation of these interventions by research institutions, the Department of Horticulture, extension agencies, and policymakers will not only enhance walnut productivity, quality, and profitability but will also strengthen the export competitiveness of Kashmiri walnuts and contribute significantly to the sustainable growth of the horticultural economy of Jammu and Kashmir.

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