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Kavita Kumari
UGC NET, Research Scholar, University Department of Commerce & Business, Administration, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar, India

Corresponding Author:
Kavita Kumari
UGC NET, Research Scholar, University Department of Commerce & Business, Administration, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar, India

Role of agri-tech and e-commerce in transforming mango cultivation in Bihar

Kavita Kumari

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Abstract
Mango cultivation in Bihar, a significant contributor to the state's agricultural economy, faces challenges such as traditional farming practices, inadequate market access, and post-harvest losses. The integration of Agri-Tech and e-commerce has emerged as a transformative solution, addressing these issues through innovation and technology. Agri-Tech platforms provide advanced tools like precision farming, disease monitoring, and weather forecasting, enabling farmers to enhance yield and quality. Additionally, digitized supply chains reduce inefficiencies, while e-commerce platforms connect farmers directly with consumers and businesses, bypassing intermediaries. These solutions ensure fair pricing, timely payments, and expanded market reach, including global export opportunities. Moreover, initiatives like blockchain-based traceability enhance consumer trust in mango quality and safety. Government support, in the form of policies and subsidies, plays a crucial role in facilitating the adoption of these technologies. However, challenges such as digital literacy, infrastructure deficits, and financing need to be addressed to maximize potential benefits. This study highlights the pivotal role of Agri-Tech and e-commerce in transforming Bihar's mango cultivation, creating a sustainable model that increases farmer income and ensures consumer satisfaction. A collaborative effort involving farmers, policymakers, and technology providers is essential to scale these innovations and position Bihar as a leader in mango production.

Keywords: Agri-Tech, E-commerce, mango cultivation, Bihar agriculture, sustainable farming solutions

Introduction
Mango cultivation in Bihar, a state renowned for its diverse agricultural output, has long been a cornerstone of rural livelihoods and economic activity. The region's unique varieties, such as Jardalu, Langra, and Maldah, are celebrated for their rich flavor and quality. However, the sector faces persistent challenges, including reliance on traditional farming practices, inadequate infrastructure, post-harvest losses, and limited market access, which constrain its potential. The integration of Agri-Tech and e-commerce offers transformative solutions to these challenges, reshaping the landscape of mango cultivation in Bihar. Agri-Tech innovations, such as precision farming, soil and crop monitoring, pest and disease management, and climate forecasting, empower farmers to optimize productivity and quality. Meanwhile, blockchain and IoT technologies enhance traceability and transparency, building consumer trust in the supply chain. Complementing these advancements, e-commerce platforms bridge the gap between farmers and markets by enabling direct-to-consumer sales, reducing dependency on intermediaries, and facilitating access to premium and export markets. These platforms not only ensure better price realization but also streamline logistics and minimize post-harvest losses. Despite their potential, barriers such as digital illiteracy, limited internet connectivity, and lack of financial resources among smallholder farmers hinder widespread adoption. Government initiatives, including subsidies, capacity-building programs, and investments in rural infrastructure, are crucial to overcoming these obstacles and fostering inclusive growth. The convergence of Agri-Tech and e-commerce in Bihar's mango sector represents a pivotal opportunity to modernize traditional practices, enhance farmer incomes, and position the state as a leader in sustainable agricultural innovation.

Current Scenario of Mango Cultivation in Bihar

The mango cultivation ecosystem in Bihar is characterized by several limitations that impact productivity and profitability. Farmers often rely on age-old methods of cultivation, which are inefficient and less adaptive to changing climatic conditions. This results in inconsistent yields and quality. Additionally, the lack of access to modern farming equipment and techniques further exacerbates the problem.

Post-harvest losses remain a critical issue in the state. Poor infrastructure for storage, transportation, and processing leads to significant wastage, affecting both farmers' income and market supply. Furthermore, the traditional supply chain, dominated by intermediaries, leaves farmers with minimal bargaining power, resulting in low income despite high consumer prices. These systemic inefficiencies necessitate a paradigm shift in the way mango cultivation and marketing are approached in Bihar.

The Role of Agri-Tech in Enhancing Mango Cultivation

Agri-Tech solutions are emerging as a game-changer for mango farmers in Bihar. These technologies offer a range of benefits, including:

1. **Precision Farming:** Advanced tools and software help monitor soil health, optimize fertilizer use, and improve irrigation efficiency, leading to higher yields and better fruit quality.
2. **Disease and Pest Management:** Technologies such as AI-driven pest monitoring systems and IoT-enabled devices provide real-time alerts, enabling farmers to take preventive measures.
3. **Weather Forecasting:** Accurate weather predictions help farmers plan activities like irrigation, spraying, and harvesting, minimizing the impact of unpredictable climatic conditions.
4. **Blockchain for Traceability:** Blockchain technology ensures transparency in the supply chain, enhancing consumer trust in the quality and origin of mangoes.

E-commerce: Bridging the Gap Between Farmers and Markets

E-commerce platforms are redefining market access for mango farmers in Bihar. Traditionally, farmers relied on local markets and intermediaries to sell their produce. This often resulted in low profit margins due to exploitative practices and limited reach. E-commerce platforms offer a direct channel to consumers, wholesalers, and export markets.

1. **Direct-to-Consumer Sales:** Platforms like Flipkart, Amazon, and local e-commerce initiatives allow farmers to sell directly to consumers, eliminating middlemen.
2. **Access to Niche Markets:** High-quality mango varieties like Jardalu can be marketed to premium customers and export markets, fetching higher prices.
3. **Better Price Realization:** Digital marketplaces ensure competitive pricing and timely payments, empowering farmers economically.
4. **Reduced Post-Harvest Losses:** By streamlining logistics and transportation, e-commerce platforms help reduce wastage and improve supply chain efficiency.

Challenges in Adoption

While Agri-Tech and e-commerce hold immense potential, their adoption in Bihar is not without challenges. Many farmers in the state have limited digital literacy, making it difficult for them to adopt technology-driven solutions. The lack of infrastructure, such as reliable internet connectivity and cold storage facilities, further complicates the integration of these innovations. Moreover, small and marginal farmers often struggle to access financing for investing in Agri-Tech tools and setting up digital marketing channels.

Government and Policy Support

The government has a critical role in facilitating the adoption of Agri-Tech and e-commerce in mango cultivation. Initiatives like subsidies for Agri-Tech adoption, training programs for farmers, and the promotion of farmer producer organizations (FPOs) can significantly boost the uptake of these solutions. Additionally, policies aimed at improving rural infrastructure, such as roads, storage facilities, and internet connectivity, are essential for creating an enabling environment.

Literature Review

1. Patel *et al*. (2015) [1] highlighted the role of precision agriculture in improving mango yields and quality. The research emphasized the use of soil sensors, drip irrigation, and pest management tools to enhance productivity. The study concluded that integrating such technologies could address the inefficiencies associated with traditional practices, especially in regions like Bihar, where mango farming is a primary source of livelihood.
2. Sharma and Rao (2017) [2] examined the issue of post-harvest losses in fruit cultivation, with a focus on mango. They found that poor infrastructure, lack of cold storage, and inefficient supply chains were major contributors to losses. The study advocated for the adoption of e-commerce platforms to create direct marketing channels and reduce wastage.
3. Kumar and Singh (2019) [3] explored the impact of e-commerce on smallholder farmers in India. Their findings showed that digital platforms like Amazon and Flipkart provided better price realization for agricultural produce, including mangoes. The study underscored the need for improving digital literacy among farmers to ensure widespread benefits from e-commerce adoption.
4. Gupta *et al*. (2020) [4] analyzed the effectiveness of Agri-Tech tools in mitigating the impacts of climate change on mango cultivation. The study emphasized the importance of weather forecasting, pest management systems, and crop health monitoring in adapting to erratic weather patterns. It also recommended integrating these tools with farmer support programs for better adoption.
5. Chopra and Verma (2021) [5] investigated the application of blockchain technology in enhancing the traceability and transparency of agricultural supply chains. The study highlighted its benefits for mango exports, where consumer trust in product quality and origin is critical. It suggested that blockchain adoption could increase demand for premium mango varieties from Bihar in both domestic and international markets.
6. The National Institute of Agricultural Extension

Management (2022) focused on the role of Agri-Tech and e-commerce in transforming Indian agriculture. It cited examples of successful initiatives in Bihar, where digital platforms enabled farmers to access markets beyond their traditional reach. The study called for greater investment in rural infrastructure and farmer training to maximize the impact of these technologies.

Research Gap

Despite the promising potential of Agri-Tech and e-commerce in transforming mango cultivation in Bihar, several gaps remain unexplored. Limited research addresses the scalability of Agri-Tech solutions for smallholder farmers with constrained resources. Studies often overlook the socio-economic barriers, such as digital illiteracy and lack of financial access, that hinder widespread adoption. Additionally, the integration of e-commerce with localized supply chains for perishable products like mangoes requires further investigation. The impact of government policies and public-private partnerships in facilitating this transformation is also under-researched. Addressing these gaps is essential to develop a comprehensive and sustainable model for Bihar's mango cultivation sector.

E-commerce's role in agricultural marketing

In recent years, the advent of Agri-Tech and e-commerce has opened new avenues for transforming agriculture, including mango cultivation. Agri-Tech, which encompasses the application of technology in agriculture, has revolutionized traditional farming methods by introducing precision tools, data-driven insights, and innovative solutions for pest management, irrigation, and crop monitoring. E-commerce platforms, on the other hand, are redefining the way agricultural products are marketed and sold, enabling farmers to connect directly with consumers and businesses, thereby eliminating intermediaries and ensuring better price realization. Here are some key points for each:

1. **Precision Agriculture in Mango Cultivation**
- Use of soil sensors, weather forecasting, and data analytics to optimize irrigation, fertilization, and pest management.
- Improves mango yield and quality while reducing resource wastage.
- Case studies of successful precision agriculture initiatives in India, especially in mango-growing regions.

2. **Post-Harvest Loss Reduction through Technology**
- The impact of cold storage, improved transportation, and packaging technologies on reducing mango spoilage.
- Integration of IoT and sensors in storage facilities to monitor and control temperature and humidity.
- Role of e-commerce in providing better logistics solutions, reducing losses by ensuring quicker transportation.

3. **Blockchain Technology in Agricultural Supply Chains**
- Blockchain's potential to enhance transparency and traceability in mango supply chains.
- Ensuring fair pricing, preventing fraud, and increasing consumer trust in the quality of mangoes.
- Example of successful blockchain applications in agricultural exports and traceability

4. **E-commerce for Direct-to-Consumer Mango Sales**
- How e-commerce platforms like Amazon, Flipkart, and regional platforms are enabling farmers to directly access national and international markets.
- Increased profitability for farmers by eliminating middlemen and ensuring better price realization.
- The challenges of packaging, delivery, and quality control in the e-commerce supply chain for perishables.

5. **Digital Literacy and Capacity Building for Farmers**
- Importance of digital literacy in enabling farmers to adopt Agri-Tech and use e-commerce effectively.
- Government and NGO-led initiatives to train farmers in using smartphones, mobile apps, and online platforms.
- Strategies for overcoming barriers such as internet connectivity and financial constraints in rural areas.

6. **Sustainable Farming Practices in Mango Cultivation**
- How Agri-Tech tools help promote sustainable farming by optimizing water usage, reducing chemical inputs, and improving soil health.
- Adoption of organic farming methods supported by technology for higher-value mango varieties.
- Role of certification schemes (like organic or fair trade) facilitated by digital platforms

7. **Impact of Government Policies on Agri-Tech Adoption**
- Government schemes, subsidies, and policies aimed at promoting the use of technology in agriculture, such as the Pradhan Mantri Fasal Bima Yojana and Digital India initiatives.
- The role of local and state governments in providing infrastructure, connectivity, and training to farmers.
- Challenges in policy implementation and ensuring inclusivity for smallholder farmers.

8. **Market Linkages and Agribusiness Development in Bihar**
- Role of Agri-Tech in connecting farmers with buyers, exporters, and retailers through digital platforms.
- Strengthening market linkages in remote areas through mobile apps and online marketplaces.
- Development of agribusiness ecosystems that support mango value chains, including processing, packaging, and branding.

Objectives of the Study

1. To analyze the impact of Agri-Tech solutions on mango productivity and quality in Bihar.
2. To evaluate the role of e-commerce in enhancing market access and price realization for mango farmers.
3. To identify challenges faced by farmers in adopting Agri-Tech and e-commerce platforms.
4. To assess the effectiveness of government policies in promoting digital agriculture and e-commerce integration.
5. To propose a sustainable model for leveraging

technology to transform mango cultivation in Bihar.

Research Methodology

This study employs a mixed-methods approach, combining qualitative and quantitative techniques to comprehensively analyze the role of Agri-Tech and e-commerce in transforming mango cultivation in Bihar.

1. Data Collection

- **Primary Data:** Surveys and structured interviews with mango farmers, e-commerce stakeholders, and Agri-Tech providers in Bihar.
- **Secondary Data:** Analysis of reports, journals, government publications, and case studies on Agri-Tech and e-commerce in agriculture.

2. Sampling

- A purposive sampling method is used to select 150 mango farmers from Bhagalpur, Darbhanga, and Muzaffarpur.
- Interviews with 10 representatives from e-commerce platforms and 5 Agri-Tech solution providers.

3. Tools for Data Collection

- Structured questionnaires to gather quantitative data on yield, income, and technology usage.
- Semi-structured interviews for qualitative insights on challenges and benefits.

4. Data Analysis Techniques

- Quantitative data analyzed using descriptive statistics (mean, standard deviation) and inferential statistics (regression analysis) to identify relationships between technology adoption and outcomes.
- Qualitative data coded thematically to extract patterns and insights.

Data Analysis

The following data represents findings from a survey conducted among 150 mango farmers in Bihar, evaluating the impact of Agri-Tech and e-commerce adoption.

Table 1: Evaluating the impact of Agri-Tech and e-commerce adoption

Category	Before Adoption	After Adoption	Change (%)
Average Yield (tons/ha)	8.2	11.5	+40.24
Income per Farmer (₹)	48,000	72,000	+50.00
Post-Harvest Losses (%)	28.0	14.0	-50.00
Market Access (number of buyers)	3	8	+166.67
E-commerce Contribution to Sales (%)	0	22.0	N/A
Cost of Production (₹/ton)	12,000	10,000	-16.67

Insights

1. **Increase in Productivity:** The adoption of Agri-Tech tools like precision farming and pest management increased the average yield per hectare by 40.24%.
2. **Higher Income:** Farmers' income improved significantly by 50% due to better quality produce and direct market access via e-commerce platforms.
3. **Reduction in Losses:** Post-harvest losses dropped by half (from 28% to 14%) with improved storage and transportation facilitated through e-commerce networks.
4. **Expanded Market Reach:** The number of buyers per farmer increased from 3 to 8, reflecting the reach of e-commerce platforms and enhanced market linkages.
5. **Cost Efficiency:** The cost of production decreased by 16.67% as technology optimized resource usage.

Limitations of the Study

This study on the role of Agri-Tech and e-commerce in transforming mango cultivation in Bihar faces several limitations. First, the sample size, though representative, is relatively small and may not capture the full diversity of farming practices and challenges across the state. Second, the data relies heavily on self-reported information from farmers, which may introduce biases or inaccuracies. Third, the analysis focuses on short-term impacts, limiting insights into the long-term sustainability and scalability of the adopted technologies. Fourth, external factors such as government policies, climatic variations, and global market trends, which significantly influence agriculture, were not fully accounted for. Lastly, the study assumes a certain level of readiness among farmers to adopt technology, potentially overlooking the challenges faced by those with limited digital literacy or financial resources. Addressing these limitations in future research could provide a more comprehensive understanding of the subject.

Importance of the Study

This study is crucial for understanding how Agri-Tech and e-commerce can revolutionize mango cultivation in Bihar, a key sector of the state's agricultural economy. By examining the impact of these technologies, the research highlights opportunities to improve productivity, reduce post-harvest losses, and enhance farmers' incomes, contributing to sustainable agricultural growth. It offers valuable insights into the potential of modern technology to address traditional challenges, such as market inefficiencies, limited access to resources, and climatic vulnerabilities. Moreover, the study underscores the importance of digital platforms in creating market linkages, ensuring fair pricing, and expanding the reach of Bihar's premium mango varieties to national and international markets. The findings could guide policymakers, Agri-Tech companies, and development organizations in designing targeted interventions to support farmers in adopting these technologies. Ultimately, this research has the potential to transform Bihar into a leading hub for mango production, benefiting farmers, consumers, and the broader economy.

Findings of the Study

1. Agri-Tech adoption led to a 40.24% increase in mango yield per hectare.
2. Farmers' income increased by 50% due to improved crop quality and market access.
3. Post-harvest losses were reduced by 50% through better storage and logistics.

4. E-commerce platforms expanded farmers' market reach, increasing buyers by 166.67%.
5. The cost of production decreased by 16.67% with efficient resource management.
6. E-commerce contributed 22% of mango sales, boosting profitability for farmers.
7. Adoption of Agri-Tech and e-commerce resulted in improved price realization for farmers.

Conclusion

In conclusion, the integration of Agri-Tech and e-commerce has shown immense potential in transforming mango cultivation in Bihar, addressing critical challenges such as low productivity, high post-harvest losses, and limited market access. The adoption of advanced technologies like precision farming, pest management, and weather forecasting has significantly enhanced the yield and quality of mangoes, leading to increased farmer incomes and reduced production costs. Additionally, e-commerce platforms have facilitated direct market access, enabling farmers to bypass intermediaries and secure better prices for their produce, thus improving their overall profitability. The reduction in post-harvest losses by 50% through better storage and transportation mechanisms highlights the positive impact of technology on supply chain management. However, the study also reveals challenges such as digital illiteracy, financial constraints, and the need for improved infrastructure that must be addressed to fully harness the benefits of these technologies. The role of government policies in supporting Agri-Tech adoption, along with targeted initiatives for rural development, is crucial for creating an enabling environment for farmers. Overall, this research underscores the transformative power of Agri-Tech and e-commerce in making mango cultivation in Bihar more efficient, sustainable, and economically viable, offering a model that can be replicated in other regions to boost agricultural growth.

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