ISSN: XXXX XXXX

Farm Science Today

Bridging Science and Farming

August 2026
Volume 1
Issue 1

Website:www.ijari.in

Email: ijariglobal@gmail.com

Letter from the Editor

*It is with great pleasure and pride that I welcome you to the inaugural issue of **Farm Science Today: A Monthly e-Magazine for the Farming Community**. This first edition marks the beginning of a platform dedicated to sharing scientific knowledge, innovative ideas, and practical insights that support sustainable agriculture and rural development. Agriculture today is undergoing are markable transformation, driven by technological advancements, changing climatic conditions, evolving consumer demands, and global challenges. In this rapidly changing scenario, timely dissemination of reliable scientific information is essential to empower farmers, students, researchers, extension professionals, and all stakeholders connected with the agricultural sector. Through Farm Science Today, we aspire to bridge the gap between scientific research and practical application by presenting informative, evidence-based, and reader-friendly articles on contemporary issues in agriculture and allied sciences.*

The inaugural issue features a diverse collection of articles that reflect both emerging opportunities and pressing challenges. Readers will discover the immense potential of seaweed as the "green gold" capable of transforming India's fisheries sector, gain insights into reducing post-harvest losses for improved food security, and explore how geopolitical developments influence agricultural resilience and global food systems. The issue also highlights the invaluable wisdom embedded in India's tribal food systems and indigenous agricultural practices, emphasizing their relevance to sustainable farming and biodiversity conservation. Finally, an overview of horticulture in Haryana presents the current status, challenges, and future prospects of one of India's most dynamic agricultural sectors.

I sincerely thank all the authors for their valuable contributions and the reviewers and editorial team for their dedication in bringing this issue to fruition. I also express my heartfelt gratitude to our readers, whose encouragement and engagement will inspire us to continuously improve the quality and relevance of this magazine.

We hope that Farm Science Today becomes a trusted source of agricultural knowledge and a platform that encourages learning, innovation, and collaboration. Your valuable suggestions, feedback, and contributions are always welcome as we continue this journey together toward a more resilient, productive, and sustainable agricultural future.

Editor
Farm Science Today

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Farm Science Today
Presenting scientific knowledge in a simple, accessible style.

ISSN (E): XXXX-XXXX
www.ijari.in
Received: 20-07-2026
Published: 02-08-2026

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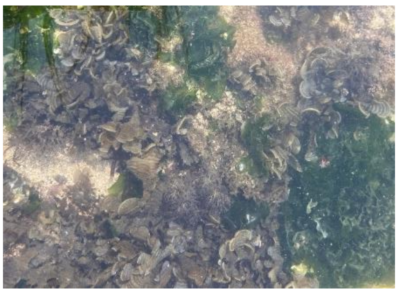
Seaweed: The Green Gold that could transform India's Fisheries Sector

Introduction

India's fisheries sector has traditionally been associated with capture fisheries, aquaculture, post-harvest handling and processing, fish marketing, and trade. However, a promising new opportunity that is steadily emerging along the country's vast coastline is seaweed farming. As an important component of the blue economy, seaweed cultivation has the potential to become a new pillar of India's fisheries sector, offering opportunities for livelihood diversification, value addition, food security, and sustainable coastal development.

Seaweeds are marine macroalgae that grow naturally in the intertidal and subtidal regions of the ocean. India is endowed with considerable seaweed diversity, with 871 seaweed species reported from the country (Kaliaperumal, 2017). The country produced approximately 72,385 tonnes of wet seaweed in 2023 (PIB, 2025). Based on their dominant pigments, seaweeds are broadly classified into three major groups: Rhodophyceae (red algae), Chlorophyceae (green algae), and Phaeophyceae (brown algae). These groups contain pigments such as chlorophylls, phycobilins, and fucoxanthins, which give them their characteristic colours.

In India, mainly the red seaweeds, *Kappaphycus alvarezii* and *Gracilaria edulis* are mainly cultivated for carrageenan and agar production. The highest seaweed diversity is reported from the coast of Gujarat and Tamil Nadu with 198 species and 282 species respectively (Jha et al., 2009; Ganesan et al., 2019). This rich diversity, combined with an extensive coastline and favourable environmental conditions, provides enormous potential for developing a vibrant seaweed industry in the country.

A nutritional and medical powerhouse

Seaweeds have attracted global attention because of their wide applications, ranging from food and pharmaceuticals to cosmetics, biofertilisers, animal feed, nutraceuticals, and other value- added products. Their nutritional composition and diverse bioactive compounds make them an increasingly important marine resource. Various bioactive compounds derived from seaweeds have demonstrated antioxidant, anti-inflammatory, antimicrobial, and other biological properties, creating opportunities for their use in nutraceuticals and functional foods. Although seaweed consumption is not yet widespread in India, some coastal communities have traditionally consumed certain species. For instance, species such as *Gracilaria* have been used by coastal communities in parts of Kerala and Tamil Nadu to prepare nutritious porridges (Dhargalkar & Pereira, 2005). Beyond food, seaweeds are already an important raw material for several industries. They are major sources of valuable phycocolloids such as agar, alginate, and carrageenan, which are used as gelling, thickening, and stabilising agents in products ranging from ice cream and dairy products to toothpaste, pharmaceuticals, cosmetics, and laboratory media. Emerging research is also exploring seaweed biomass as a raw material for biofuels, bioplastics, biofertilisers, and other sustainable products.

Seaweed as a Blue Carbon Sink

In addition to their economic importance, seaweeds provide several ecosystem services and also serve as a blue carbon sink. Through photosynthesis, seaweeds absorb carbon dioxide and incorporate carbon into their biomass. Globally, macroalgae are estimated to contribute to substantial carbon fixation, with some studies estimating that they could sequester approximately 173 million tonnes of carbon annually (Krause-Jensen & Duarte, 2016).

Seaweed ecosystems and responsible seaweed farming may also contribute to nutrient removal and improved water quality, while natural seaweed habitats provide shelter and feeding grounds for a variety of marine organisms. However, the climate benefits of seaweed farming depend on factors such as cultivation methods, biomass fate, harvesting practices, and long-term carbon storage.

India's Untapped Seaweed Potential

Despite its considerable potential, India currently contributes less than 1% of global seaweed production. With a coastline of approximately 11,098.81 km and an Exclusive Economic Zone (EEZ) of about 2.02 million km², India has significant scope for expanding seaweed cultivation. Estimates by ICAR-CMFRI indicated that the country's potential seaweed production could reach nearly 10 million tonnes annually, highlighting the enormous gap between existing production and potential.

The domestic consumption of seaweed in India remains relatively low compared with countries in East and Southeast Asia, where seaweeds form an important part of traditional diets. This, however, also presents an opportunity. India can explore both domestic consumption and export markets, particularly for high-quality edible seaweed and value-added products.

At the same time, changing food preferences among younger consumers are creating new possibilities within India. In several parts of the country, including the northeastern states, there is growing interest in foods influenced by East and Southeast Asian cuisines, where seaweeds are commonly consumed. Promoting suitable edible seaweed species and developing culturally appropriate products could therefore create new domestic markets. However, such expansion should be guided by food safety standards, nutritional awareness, species-specific assessments, and consumer education.

Seaweed Farming and Integration with Other Aquaculture Systems

Seaweed farming is a relatively low-input and environmentally friendly form of marine farming. It generally requires limited infrastructure compared with many conventional aquaculture systems and does not require freshwater, feed, or agricultural land. Depending on the species and local environmental conditions, seaweed can be cultivated using methods such as floating rafts, long-lines, monolines, and tube nets.

Healthy seed material, including vegetative fragments or seedlings, is attached to ropes, nets, or other culture structures. These structures are then placed and anchored in suitable coastal waters, where the seaweed grows by utilising naturally available sunlight and nutrients. Regular monitoring is necessary to manage fouling organisms, grazing, disease, storm damage, and other environmental factors. Depending on the species and farming conditions, seaweed may be harvested within approximately 45–90 days.

One of the most promising aspects of seaweed farming is its potential for integration with other aquaculture activities. In Integrated Multi-Trophic Aquaculture (IMTA) systems, seaweeds can be cultured alongside fish and shellfish. Different organisms occupy different ecological niches and utilise nutrients generated within the farming system, potentially improving resource efficiency and reducing environmental impacts.

ICAR-CMFRI has worked on IMTA models integrating seaweed cultivation with cage fish farming and bivalve culture, demonstrating the potential of integrated coastal production systems. Research has also explored the incorporation of seaweeds into shrimp farming systems, with promising results indicating potential benefits for water quality and shrimp performance under suitable conditions.

Such integrated systems could be particularly valuable for coastal communities because they allow farmers to diversify production and income rather than depending on a single commodity.

Government Initiatives and Institutional Support

Recognising the potential of seaweed cultivation, the Government of India has identified it as an important component of blue economy development. Under the Pradhan Mantri Matsya Sampada Yojana (PMMSY), support has been provided to promote seaweed cultivation and related infrastructure.

Several initiatives are being undertaken to strengthen the seaweed sector, including the development of seaweed clusters, seed banks, improved planting material, processing facilities, and value-addition infrastructure. The Mandapam Regional Centre of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) has been designated as a Centre of Excellence for seaweed development, while the Lakshadweep Islands have been identified as a seaweed cluster. The Department of Fisheries, Government of India, has also approved projects for establishing seaweed seed banks in Tamil Nadu, Dadra and Nagar Haveli and Daman & Diu, and Lakshadweep (PIB, 2025).

Empowering Coastal Communities

The greatest potential of seaweed farming lies in its ability to diversify livelihoods and empower coastal communities. Climate change is already influencing the distribution and productivity of marine fish stocks, while overexploitation, habitat degradation, pollution, and other pressures continue to challenge the sustainability of capture fisheries. In this context, seaweed farming can provide an alternative or supplementary livelihood based on a renewable marine resource. For small-scale fishers and fisherwomen, seaweed cultivation can provide an additional source of income. For fisherwomen, in particular, the opportunities extend beyond cultivation. They can participate in harvesting, drying, processing, packaging, product development, and marketing, thereby increasing their involvement throughout the fisheries value chain. The real economic opportunity, therefore, lies not only in producing and selling raw seaweed but also in value addition. Developing seaweed-based foods, nutraceuticals, cosmetics, biofertilisers, animal feed, biostimulants, and other products can generate employment at multiple stages of the value chain while retaining a greater share of the economic value within coastal communities. Initiatives across coastal India have already demonstrated the potential of seaweed cultivation to create new livelihood opportunities, particularly for women.

Challenges

Despite its enormous promise, the seaweed sector faces several challenges. The availability of high-quality planting material, access to suitable farming sites, extreme weather events, diseases, biofouling, market fluctuations, and limited processing infrastructure can all affect production and profitability. At present, much of the economic potential remains untapped because the sector requires stronger linkages between seed production, cultivation, harvesting, processing, storage, value addition, and marketing. A farmer may produce high-quality seaweed, but without reliable buyers, adequate processing facilities, and stable market linkages, the economic returns may remain uncertain. The development of seaweed parks, clusters, seed banks, processing facilities, and centres of excellence can help address these limitations. At the same time, greater investment in research and development is required to identify commercially promising species, improve cultivation techniques, develop disease-resistant and stress-tolerant strains, and enhance post-harvest technologies.

Environmental sustainability must also remain at the centre of seaweed sector development. Not every coastal location is suitable for cultivation, and poorly planned expansion could potentially create conflicts with capture fisheries, navigation, tourism, conservation areas, and other coastal activities. Therefore, seaweed farming should be developed through scientific site selection, environmental monitoring, marine spatial planning, and community participation.

Conclusion

India stands at an important juncture in the development of its seaweed sector. The country possesses a long coastline, rich seaweed biodiversity, established fisheries communities, scientific expertise, and growing policy support. What is needed now is a coordinated approach that brings together research institutions, government agencies, private industries, entrepreneurs, fishers, fisherwomen, cooperatives, and local communities. Continued investment in research and development particularly in seed production, tissue culture, improved germplasm, stress-tolerant strains, sustainable cultivation technologies, and value-added product development will be crucial for scaling up the industry. Public-private partnerships can help bridge gaps in processing, marketing, and investment, while community-based models can ensure that the benefits of this emerging sector reach the people who depend most directly on coastal resources. Greater public awareness about suitable edible species, their nutritional value, preparation methods, and food safety can help stimulate domestic consumption and create new markets. Seaweed also offers an opportunity to rethink the future of fisheries. As climate change, overfishing, habitat degradation, and environmental pollution place increasing pressure on conventional marine fisheries, livelihood diversification is becoming more important than ever. Seaweed farming, as a renewable marine resource, can complement capture fisheries and aquaculture while creating new opportunities for income and employment. If developed responsibly, it could contribute to food security without competing for freshwater or agricultural land, create alternative livelihoods for coastal communities, empower fisherwomen, generate new industries, and strengthen India's blue economy.

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Author Declaration

All three authors contributed to the conception, preparation, writing, and revision of this article. All authors have read and approved the final version of the article and jointly accept responsibility for its content. The authors also accept joint responsibility for addressing any disputes or claims that may arise concerning authorship or intellectual property related to this article.

Farm Science Today

Presenting scientific knowledge in a simple, accessible style.

ISSN (E): XXXX-XXXX
www.ijari.in
Received: 20-07-2026
Published: 02-08-2026

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Post-Harvest Wastage in India: Challenges, Government Initiatives, and the Way Forward

Introduction

India occupies a prominent position in global agriculture and is recognized as the world's second-largest producer of fruits and vegetables while also being one of the leading producers of cereals, pulses, milk, spices, and several other agricultural commodities. Agriculture continues to be the backbone of the Indian economy, supporting nearly half of the country's workforce and contributing significantly to national food security and rural livelihoods. Despite these impressive achievements in agricultural production, India continues to experience substantial losses after crops are harvested. Every year, millions of tonnes of food grains, fruits, vegetables, and other perishable commodities are damaged or spoiled before reaching consumers. These losses, commonly referred to as post-harvest losses, represent one of the most serious challenges confronting Indian agriculture.

They not only reduce farmers' incomes but also increase food prices, undermine food security, and result in the waste of valuable natural resources such as land, water, fertilizers, energy, and labour. Post-harvest losses encompass both quantitative losses, where the physical quantity of produce is reduced, and qualitative losses, where the nutritional value, marketability, and consumer acceptability of agricultural products decline because of poor handling, inadequate storage, inefficient transportation, and delayed marketing. According to estimates by the Ministry of Food Processing Industries and studies conducted by the ICAR–Central Institute of Post-Harvest Engineering and Technology (ICAR-CIPHET), India loses agricultural produce worth over ₹1.5 lakh crore annually due to deficiencies in post-harvest management. In a country where food security and farmer welfare remain major policy priorities, reducing post-harvest losses has become as important as increasing agricultural production itself.

Magnitude of Post-Harvest Losses in India

Post-harvest losses have emerged as a major concern for India's agricultural economy because they significantly reduce the effective availability of food despite high production levels. Various studies conducted by government agencies indicate that India loses between 15 and 30 percent of its agricultural production after harvesting, with the highest losses occurring in perishable commodities such as fruits, vegetables, flowers, dairy products, fish, and meat. The ICAR-CIPHET national assessment estimated that the economic value of these losses exceeds ₹92,000 crore annually, while more recent government estimates place the overall economic burden at over ₹1.52 lakh crore. These losses occur at every stage of the supply chain, beginning from harvesting and extending through threshing, drying, grading, packaging, transportation, storage, wholesale marketing, retail distribution, and finally consumption. The consequences of these losses extend beyond financial costs. Every kilogram of food that is wasted represents a loss of irrigation water, fertilizers, electricity, fuel, labour, and cultivated land. In addition, decomposing food releases methane, a greenhouse gas that contributes significantly to climate change.

Thus, post-harvest losses have economic, social, environmental, and nutritional implications that directly affect both farmers and consumers.

Causes of Post-Harvest Wastage

One of the primary causes of post-harvest wastage in India is the inadequate development of cold-chain infrastructure. Fruits, vegetables, milk, fish, meat, and several other commodities require temperature-controlled storage and transportation immediately after harvest in order to maintain their quality and shelf life. However, only a limited proportion of India's perishable produce benefits from an uninterrupted cold chain. In many rural areas, harvested produce remains exposed to high temperatures for several hours before reaching collection centres or markets. This accelerates respiration, moisture loss, microbial activity, and physiological deterioration, resulting in rapid spoilage. The shortage of pre-cooling facilities, refrigerated vehicles, cold storages, ripening chambers, and controlled-atmosphere warehouses continues to be a major bottleneck in India's agricultural supply chain.

Another important factor contributing to post-harvest losses is the poor condition of storage infrastructure. A significant proportion of farmers continue to store grains and other produce in traditional storage structures that provide little protection against moisture, rodents, insects, birds, or fungal infestations. Seasonal rains and fluctuations in humidity further aggravate storage losses. Although scientific warehouses and steel silos have expanded in recent years, their availability remains inadequate, particularly in remote rural regions where small and marginal farmers constitute the majority of agricultural producers.

Transportation constraints also play a crucial role in increasing post-harvest losses. Agricultural commodities frequently travel long distances from production centres to wholesale markets, processing industries, or export terminals. Poor rural roads, traffic congestion, multiple loading and unloading operations, and the limited availability of refrigerated transport expose produce to physical damage and prolonged transit times. Delays in transportation are particularly harmful for highly perishable commodities, whose market value declines rapidly if they are not delivered within a short period after harvest.

The continued use of traditional harvesting and post-harvest handling methods also contributes significantly to wastage. Many farmers harvest crops manually without proper knowledge of crop maturity, harvesting techniques, or scientific handling practices. Mechanical injuries caused during harvesting, improper sorting, rough handling, and inadequate packaging reduce both the quality and marketability of produce. Similarly, inadequate grading and packaging increase the likelihood of damage during transportation, leading to considerable economic losses.

An equally important challenge is the insufficient development of food processing industries in agricultural production clusters. During bumper harvests, farmers often face a sharp decline in market prices because there are limited facilities for processing surplus produce into value-added products such as juices, pulp, dehydrated vegetables, frozen foods, sauces, or pickles. Consequently, farmers are forced to dispose of their produce at distress prices or leave it unharvested in fields, resulting in enormous wastage.

Government Initiatives

Recognizing the seriousness of post-harvest losses, the Government of India has implemented several schemes aimed at strengthening agricultural infrastructure and improving supply chain efficiency. The **Mission for Integrated Development of Horticulture (MIDH)** supports the establishment of cold storage facilities, pack houses, ripening chambers, and integrated post-harvest management infrastructure to reduce spoilage of fruits and vegetables. The **Agriculture Infrastructure Fund (AIF)** provides medium- and long-term financial assistance for constructing warehouses, cold chains, primary processing centres, grading units, and community storage facilities. These investments seek to bridge critical infrastructure gaps and encourage private sector participation in agricultural value chains.

The Government has also introduced the **National Agriculture Market (e-NAM)** to digitally integrate agricultural markets across the country. By facilitating transparent price discovery and improving market access, e-NAM reduces unnecessary delays in marketing agricultural produce and enables farmers to receive better prices. Likewise, the promotion of **Farmer Producer Organizations (FPOs)** enables small farmers to aggregate their produce, undertake primary processing, improve storage, negotiate better prices, and establish stronger market linkages. Through collective action, FPOs reduce transaction costs and enhance farmers' bargaining power.

Another significant initiative is **Operation Greens**, which was initially launched for Tomato, Onion, and Potato (TOP) crops before being expanded to cover all fruits and vegetables. The scheme seeks to stabilize prices, strengthen cold-chain infrastructure, promote food processing, and reduce seasonal wastage caused by market gluts. Similarly, the **PM Kisan SAMPADA Yojana** promotes integrated cold chains, agro-processing clusters, mega food parks, and food preservation facilities, thereby encouraging value addition and reducing post-harvest losses across the country.

Conclusion

India has made remarkable progress in increasing agricultural production during the past several decades, yet the persistence of high post-harvest losses continues to undermine the benefits of this achievement. Every year, valuable agricultural produce worth thousands of crores are lost because of inadequate storage facilities, poor transportation, weak cold-chain infrastructure, limited processing capacity, and inefficient marketing systems. These losses directly reduce farmers' incomes, increase food prices for consumers, waste scarce natural resources, and threaten national food security.

Reducing post-harvest wastage should therefore become an integral component of India's agricultural development strategy. Investments in scientific storage, modern logistics, food processing industries, digital agriculture, farmer training, and rural infrastructure can substantially reduce these losses. Equally important is the promotion of Farmer Producer Organizations, public-private partnerships, and technological innovations that improve the efficiency of agricultural value chains. Saving food that has already been produced is often more economical and environmentally sustainable than increasing production through additional use of land and water. If India succeeds in significantly reducing post-harvest losses, it will not only strengthen food security and improve farmers' livelihoods but also contribute meaningfully to sustainable agricultural development and the achievement of national and global development goals.

Farm Science Today

Presenting scientific knowledge in a simple, accessible style.

ISSN (E): XXXX-XXXX
www.ijari.in
Received: 08-07-2026
Published: 02-08-2026

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The Straitjacket on the Soil: Forging Agricultural Resilience in the Age of Geopolitical Shocks

Introduction

Every seed sown today represents far more than the promise of a future harvest; it symbolizes humanity's determination to withstand the growing challenges of climate change, resource scarcity, market volatility, and geopolitical instability. Agriculture, once governed primarily by seasonal rainfall and local market dynamics, has evolved into an interconnected global enterprise where events unfolding thousands of kilometres away can directly influence the livelihood of farmers. In today's world, agriculture is no longer expected merely to feed the growing population—it must first remain resilient against an increasingly uncertain global environment. On a quiet March morning in Sangrur, Punjab, Rameshwar stands beside his wheat field, not admiring the ripening crop but anxiously examining his farm accounts. For decades, his agricultural decisions were guided by monsoon rains, local markets, and seasonal labour availability. However, in 2026, the greatest threat to his next crop lies far beyond India's borders. Rising fertilizer prices, fuel costs, and disruptions in international trade have transformed his production economics. Although his current harvest appears satisfactory, securing essential fertilizers such as urea and diammonium phosphate (DAP) for the next cropping season has become increasingly difficult and expensive. His situation illustrates how deeply global geopolitical developments have become intertwined with the realities of modern agriculture.

The geopolitical tensions affecting the Persian Gulf have highlighted the vulnerability of global agricultural supply chains. The Strait of Hormuz, one of the world's busiest maritime trade routes, serves as a critical corridor for crude oil, liquefied natural gas (LNG), and fertilizer raw materials. Any disruption in this strategic waterway immediately affects international shipping, increases transportation costs, and creates uncertainty in global commodity markets. Unlike previous food crises driven primarily by shortages in grain production, recent geopolitical disturbances have demonstrated that agricultural systems can be severely affected through disruptions in essential farm inputs. Even when sufficient food stocks exist globally, the affordability and availability of fertilizers, fuel, and other agricultural inputs become major constraints for future food production. Modern agriculture depends heavily on energy resources, making the relationship between fossil fuels and food production stronger than ever before. Nitrogen fertilizers are manufactured primarily using natural gas as a feedstock, while diesel powers tractors, irrigation pumps, harvesters, and transportation networks. Consequently, increases in crude oil and natural gas prices rapidly translate into higher cultivation costs. Rising energy prices not only increase fertilizer manufacturing expenses but also elevate the costs of irrigation, mechanized farming, food processing, cold storage, and transportation. Farmers therefore experience the consequences of international energy crises directly through higher production costs, even though they may never witness the geopolitical events responsible for these disruptions.

For developing countries such as India, these challenges are further compounded by dependence on imported fertilizers and raw materials. Although India possesses substantial domestic fertilizer manufacturing capacity, the country continues to import significant quantities of urea, DAP, muriate of potash (MOP), rock phosphate, sulphur, and liquefied natural gas. Disruptions in global fertilizer trade therefore create supply shortages, increase subsidy burdens on the government, and ultimately raise cultivation costs for farmers. Small and marginal farmers, who constitute the majority of India's agricultural workforce, are particularly vulnerable because they possess limited financial capacity to absorb sudden increases in production expenses. As fertilizer prices rise alongside fuel costs, profit margins shrink considerably, forcing many farmers to reduce fertilizer application, delay cultivation operations, or incur additional debt.

These economic pressures coincide with another equally serious challenge—climate change. Agriculture across the globe is increasingly affected by erratic rainfall patterns, prolonged droughts, severe floods, heat waves, cyclones, and changing pest dynamics. Climate change has transformed weather variability from an occasional concern into a persistent threat to agricultural productivity. The increasing frequency of compound climate events, where droughts are followed by extreme heat or floods occur after prolonged dry periods, places enormous pressure on farming systems. Such climatic instability not only reduces crop yields but also increases irrigation demand, accelerates groundwater depletion, and raises production costs. Consequently, agriculture now faces the dual challenge of adapting simultaneously to environmental stress and global economic uncertainty.

Among all natural resources supporting agriculture, water has emerged as perhaps the most critical concern. Agriculture accounts for nearly seventy percent of global freshwater withdrawals, and excessive groundwater extraction has significantly lowered water tables in several agriculturally important regions, including Punjab, Haryana, Rajasthan, and parts of Gujarat. Climate change further intensifies this crisis by creating irregular rainfall patterns and reducing groundwater recharge. As water becomes increasingly scarce, farmers often resort to over-extraction of groundwater, creating a vicious cycle of declining aquifers, soil degradation, and increasing production costs. Sustainable water management has therefore become central to ensuring future agricultural resilience.

Recognizing these emerging challenges, the Government of India has introduced several initiatives aimed at strengthening agricultural resilience and reducing farmers' vulnerability. The promotion of Farmer Producer Organizations (FPOs) has enabled small and marginal farmers to collectively purchase inputs, improve market access, and negotiate better prices for their produce. Schemes such as the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) encourage efficient irrigation and water conservation, while the Soil Health Card programme promotes balanced nutrient management based on scientific soil analysis. The PM-PRANAM initiative seeks to reduce excessive dependence on chemical fertilizers by encouraging sustainable nutrient management practices, and the National Mission on Sustainable Agriculture supports climate-resilient farming technologies and improved natural resource management. Together, these programmes represent important steps toward strengthening India's agricultural sector against future uncertainties.

At the same time, the long-term sustainability of agriculture will require a gradual transition from conventional input-intensive farming toward more regenerative production systems. Biofertilizers, microbial inoculants, and organic nutrient sources are emerging as viable alternatives capable of reducing dependence on synthetic fertilizers while improving soil health. Advances in precision agriculture—including drone-based spraying, remote sensing, Global Positioning System (GPS)-guided machinery, Internet of Things (IoT)-based soil sensors, and artificial intelligence-driven crop advisory systems—are enabling farmers to optimize fertilizer application, reduce chemical wastage, and improve input-use efficiency. These technologies not only reduce production costs but also minimize environmental impacts, making agriculture both economically and ecologically sustainable.

Equally important is the concept of circular agriculture, which emphasizes efficient utilization of available resources through recycling and value addition. Composting crop residues, producing biochar, integrating livestock with crop production, utilizing renewable energy for irrigation, and adopting integrated farming systems can substantially reduce dependence on imported agricultural inputs. Such resource-efficient production models strengthen farm resilience while simultaneously improving soil fertility, reducing greenhouse gas emissions, and enhancing long-term sustainability.

The challenges confronting global agriculture today extend far beyond the boundaries of individual farms. Geopolitical conflicts, climate change, water scarcity, energy insecurity, and market volatility have become deeply interconnected, creating complex risks that cannot be addressed through conventional approaches alone. Building agricultural resilience therefore requires coordinated efforts involving governments, scientific institutions, extension agencies, private industries, and farming communities. Investments in domestic fertilizer production, renewable energy, climate-resilient crop varieties, digital agriculture, efficient irrigation, improved storage infrastructure, and farmer education will play a crucial role in reducing future vulnerabilities. The agricultural landscape of the coming decade will be defined not merely by the quantity of food produced but by the resilience of the systems that produce it. As the sun sets over Rameshwar's wheat fields in Punjab, the question before him is no longer confined to the size of his harvest; it concerns whether agriculture itself can adapt to a future shaped by geopolitical uncertainty, climatic extremes, and resource limitations. The answer lies in embracing innovation, strengthening sustainability, conserving natural resources, and fostering international cooperation. Every seed protected today represents not only the promise of the next harvest but also an investment in the food security, economic prosperity, and environmental resilience of generations yet to come.

Farm Science Today

Presenting scientific knowledge in a simple, accessible style.

ISSN (E): XXXX-XXXX
www.ijari.in
Received: 28-07-2026
Published: 02-08-2026

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Tribal food systems in India: learning from indigenous agriculture

Introduction

Food is much more than a source of nourishment for India's tribal communities; it is an expression of culture, identity, ecological wisdom, and an intimate relationship with nature. Long before the concepts of sustainable agriculture, climate-smart farming, biodiversity conservation, and organic food entered scientific discussions, indigenous communities had already developed farming systems that respected natural ecosystems while ensuring food and nutritional security. Their traditional food systems, shaped by centuries of observation and adaptation, continue to offer valuable lessons for building resilient agriculture in an era of climate change and resource depletion.

India possesses one of the richest tribal heritages in the world. According to the 2011 Census, Scheduled Tribes constitute nearly 8.9 percent of the country's population, making India home to the second-largest tribal population after Africa. These communities, popularly known as Adivasis, meaning "original inhabitants," have preserved unique languages, customs, agricultural traditions, and food cultures despite rapid social and economic transformations. Recognizing their distinct identity, the Constitution of India classifies these communities as Scheduled Tribes under Articles 366(25) and 342, providing constitutional safeguards for their socio-economic development. Beyond their cultural significance, tribal societies represent living repositories of indigenous knowledge, particularly in the fields of agriculture, biodiversity conservation, forest management, and sustainable food production. Unlike modern food systems that often depend on intensive external inputs and global supply chains, tribal food systems are deeply rooted in local ecosystems. Food is not selected on the basis of commercial value or market demand but according to seasonal availability, ecological sustainability, and traditional knowledge accumulated over generations. Forests, rivers, grasslands, and cultivated fields together function as natural food baskets, supplying cereals, wild vegetables, fruits, tubers, mushrooms, medicinal plants, fish, honey, and livestock products throughout the year. Every season brings a distinct variety of foods, ensuring dietary diversity while preventing excessive exploitation of natural resources.

Traditional tribal diets are remarkably balanced and nutritionally diverse. Millets such as finger millet, kodo millet, little millet, foxtail millet, sorghum, and maize remain staple foods across many tribal regions because they are hardy, drought tolerant, and well adapted to local climatic conditions. Alongside these cereals, tribal communities consume pulses, leafy vegetables, edible forest greens, bamboo shoots, wild mushrooms, roots, tubers, fruits, medicinal herbs, fish, poultry, and locally available animal products. Cooking methods are generally simple, involving boiling, roasting, steaming, or fermentation, which help preserve nutritional quality while requiring minimal fuel and processing. Natural sweeteners such as honey and mahua flowers further illustrate the close relationship between food and forests. The diversity of tribal food systems reflects India's remarkable ecological variation. In the North-Eastern Himalayan region, bamboo shoots, fermented vegetables, tree beans (Yongchak), colocasia leaves, fern shoots, chayote, banana stem, and the famous Bhut Jolokia chilli form important components of daily diets.

Seasonal wild greens collected from forests provide essential vitamins and minerals while also serving medicinal purposes. In contrast, the North-Western Himalayan tribes depend more heavily on barley, buckwheat, wheat, maize, pulses, dairy products, and traditional foods such as tsampa, thukpa, khambir, siddu, and madra, all of which are well suited to high-altitude environments and cold climatic conditions.

Central India's tribal communities have evolved food systems that depend largely on forests and coarse cereals. Millets such as kodo and kutki remain dietary staples, while nourishing preparations like pej provide energy during strenuous agricultural work. Forests contribute edible tubers, mushrooms, leafy greens, medicinal plants, and honey, whereas mahua flowers occupy a unique place by serving as both food and a culturally significant fermented beverage. Similar patterns are observed among tribal communities of western India, where ragi, jowar, maize, bamboo shoots, wild berries, forest vegetables, freshwater fish, and seasonal foods form the basis of nutrition. Minimal processing and reliance on fresh seasonal produce ensure high nutritional value while reducing dependence on external inputs. Southern India's tribal food systems are equally diverse, combining cultivated crops with rich forest resources. Finger millet, little millet, foxtail millet, rice, sorghum, and maize are commonly consumed alongside horse gram, pigeon pea, cowpea, bamboo shoots, jackfruit, wild mushrooms, honey, edible berries, and roasted tubers. Buffalo milk and dairy products remain central to the diet of communities such as the Todas, while fermented millet beverages and herbal infusions continue to play important cultural roles. In the Andaman and Nicobar Islands, tribal diets are shaped by marine ecosystems, with fish, shellfish, coconut, breadfruit, pandanus, yam, taro, bananas, and forest fruits providing highly nutritious and locally adapted food sources.

The remarkable resilience of tribal food systems is closely linked to indigenous agricultural practices that have evolved over centuries through continuous interaction with local environments. Indigenous agriculture is founded upon the principles of ecological balance, efficient resource use, and long-term sustainability rather than short-term productivity alone. Farming practices such as mixed cropping, agroforestry, crop rotation, seed conservation, organic manuring, rainwater harvesting, and community-based resource management enable tribal farmers to maintain soil fertility, conserve biodiversity, and reduce vulnerability to climatic fluctuations without excessive dependence on chemical fertilizers or pesticides.

At the heart of these practices lies indigenous knowledge, a dynamic body of traditional wisdom accumulated through generations of observation and experimentation. Tribal communities possess detailed understanding of local soils, rainfall patterns, medicinal plants, pest behaviour, and crop adaptation. Their seed-saving traditions preserve numerous indigenous crop varieties that are naturally tolerant to drought, pests, diseases, and poor soils, thereby maintaining valuable genetic diversity that has become increasingly important under changing climatic conditions. Soil fertility is sustained through composting, farmyard manure, crop residues, and natural biofertilizers, while crop rotation and fallowing help restore soil nutrients and prevent land degradation. Water conservation has always occupied a central place in indigenous agriculture. Traditional systems such as bamboo drip irrigation in the North-East, terrace cultivation in hilly regions, rainwater harvesting structures, and step wells demonstrate sophisticated engineering developed without modern technology. These practices maximize water-use efficiency while reducing dependence on groundwater extraction. Likewise, pest management relies largely on biodiversity, mixed cropping, companion planting, and agroforestry, allowing ecological interactions to suppress pests naturally instead of relying heavily on synthetic pesticides.

Perhaps the most significant feature of indigenous agriculture is its close integration with cultural values and ecological ethics. Agricultural operations are synchronized with seasonal cycles, local festivals, and community traditions, reinforcing respect for forests, water bodies, wildlife, and biodiversity. Such agroecological systems recognize that human well-being depends upon maintaining healthy ecosystems rather than maximizing production at the expense of natural resources.

Among India's indigenous farming systems, Jhum or shifting cultivation practiced across North-Eastern India remains one of the most widely discussed. Although often misunderstood as environmentally destructive, traditional Jhum was originally designed with long fallow periods that allowed forests and soils to regenerate naturally. The system promotes mixed cropping, conserves indigenous seed varieties, supports agrobiodiversity, and requires very few external inputs. While shortening of fallow cycles due to population pressure has created ecological concerns in certain regions, many ecological principles underlying traditional Jhum continue to provide valuable lessons for sustainable land management and climate-resilient agriculture. Another outstanding example is Odisha's millet-based tribal farming system. Traditional millets such as ragi, little millet, and kodo millet have sustained tribal communities for centuries because of their remarkable tolerance to drought, poor soils, and climatic variability. Recent initiatives such as the Shree Anna Abhiyan have revived numerous indigenous millet varieties while promoting improved cultivation practices through the System of Millet Intensification (SMI). The integration of millet cultivation with eco-tourism in districts such as Koraput and Kandhamal has further created livelihood opportunities while showcasing the nutritional, cultural, and ecological significance of indigenous food systems.

As the world grapples with climate change, biodiversity loss, nutritional insecurity, and environmental degradation, tribal food systems offer practical solutions grounded in centuries of experience. Their emphasis on dietary diversity, local resource utilization, ecological farming, and community stewardship aligns closely with the principles of sustainable agriculture and the Sustainable Development Goals. Rather than viewing indigenous knowledge as a relic of the past, it should be recognized as a valuable scientific resource capable of complementing modern agricultural research. The future of sustainable agriculture lies not in replacing indigenous wisdom with modern technology but in thoughtfully integrating the strengths of both systems. Scientific innovations can enhance productivity and efficiency, while indigenous knowledge provides resilience, biodiversity conservation, and ecological sustainability. By documenting, preserving, and promoting tribal food systems and indigenous agricultural practices, India can safeguard an invaluable cultural heritage while strengthening food security and climate resilience for future generations. The wisdom preserved within tribal communities demonstrates that truly sustainable agriculture is achieved not through intensive exploitation of nature, but through respectful coexistence with it.

Farm Science Today

Presenting scientific knowledge in a simple, accessible style.

ISSN (E): XXXX-XXXX
www.ijari.in
Received: 31-07-2026
Published: 02-08-2026

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Horticulture in Haryana: Present status, Challenges, and Emerging Prospects

Introduction

Horticulture has emerged as a vital and diversified sector in India's agricultural landscape, playing a key role in ensuring nutritional security, generating employment, and enhancing the income of farmers. In this context, Haryana is rapidly gaining prominence as one of the leading states in the field of horticulture. The state's agro-climatic conditions are conducive to the cultivation of a wide variety of horticultural crops, including fruits, vegetables, spices, mushrooms, and flowers. In the year 2023–24, horticultural crops in Haryana were cultivated over an area of approximately 4.12 lakh hectares, representing 6.28% of the state's total gross cropped area. The sector recorded a substantial output, with total horticultural production reaching 68.43 lakh metric tonnes. Out of total horticultural area nearly 80% of the total area is under vegetable cultivation, with the remaining area devoted to fruits, spices, and other high-value crops. Changing consumption patterns driven by rising per capita incomes, urbanization, and awareness about health and nutrition are shifting dietary preferences towards fruits and vegetables. This trend presents a strategic opportunity for Haryana's farmers, especially small and marginal ones, to transition from traditional crops to high-value horticultural produce. Crop diversification through horticulture is not just a means to increase farm income but also a sustainable pathway to strengthen the rural economy and reduce risks associated with monoculture. As Haryana continues to expand its horticultural footprint, it becomes imperative to explore the current status, growth trends, critically examines the challenges that hinder its full potential, and highlights the emerging prospects that can shape a more resilient and economically vibrant horticultural future for the state.

Geography and Agro climatic Condition of Haryana

Haryana is a landlocked north-western Indian state, extending from 27°39′–30°35′ N to 74°28′–77°36′ E and spanning approximately 44,212 km². Its terrain transitions from the fertile Indo-Gangetic plains to the northeastern Shivalik foothills, western Bagar semi-desert, and scattered Aravalli outcrops in the south. Climatically, the state exhibits a subtropical continental climate with extremely hot summers (up to ~45 °C), cool winters (3–9 °C), and a monsoon season (July–September) delivering about 400 mm of average annual rainfall. Haryana's agriculture is shaped by three agro-climatic zones—sub-humid (Shivalik belt), semi-arid (central plains), and arid (western and south-western districts)—which guide crop suitability and resource management.

Present status of Horticulture in Haryana

Horticulture in Haryana has emerged as a vital sector, significantly contributing to agricultural diversification, farmers' income, and employment generation. Presently, the state has around 4.13 lakh hectares under horticultural crops, producing approximately 6.82 million metric tonnes annually (Table 1). Vegetables dominate the sector with 334,995 hectares of area and over 5.91 million metric tonnes of production. Fruit cultivation covers 70,218 hectares, yielding 856,321 metric tonnes, with citrus, mango, and guava being major crops. Floriculture, though smaller in area (1,692 hectares), has shown rapid growth, producing 19,613 metric tonnes and over 73 million flower sticks. Spices are grown on 5,634 hectares, producing 37,171 metric tonnes, while medicinal crops, though limited to 347 hectares, are gaining traction due to rising demand for herbal products. Mushroom cultivation, a land-independent activity, is practiced over 1.58 million square meters, yielding 15,339 metric tonnes. This comprehensive data underscores Haryana's growing strength in horticulture and its promising future as a hub for high-value crop production. In fruits citrus, guava and mango are the major crop grown in Haryana.

Haryana's horticulture sector shows strong diversity, with citrus leading among fruits, covering 45% of the fruit area and contributing 42% of fruit production. Guava and mango follow with 30% and 14% area shares, respectively. In vegetables, cucurbits have the highest area (21%) and production (24%), while potato alone contributes 17% of total vegetable output. Garlic dominates the spice segment with over 80% of production. In floriculture, marigold leads in area, and gladiolus in cut flower production. Though small, medicinal crops like aloe vera show emerging potential, reflecting Haryana's shift towards high-value horticulture (Table2).

Table 1: Area and Production statistics of Horticulture in year 2023-24

Crop	Area (Ha.)	Production (MT)
Fruits	70218.92	856320.66
Vegetable	334995.34	5914687.09
Flowers	1692.2	19613 and (73295960 Sticks)
Spices	5633.58	37171
Medicinal crops	346.7	230.4
Mushroom	1583185	15339.5
Total	412886.74	6823748.65

Major Horticultural Zones of Haryana

Haryana's agro-climatic diversity supports the cultivation of both tropical and sub-tropical fruits and vegetables. In fruits citrus is mainly grown in Sirsa, Fatehabad, Hisar, and Bhiwani, while mango thrives in Yamunanagar, Panchkula, and Ambala. Guava is cultivated in almost all districts of Haryana with prominence in Hisar, Jind, Nuh, Sonepat. In arid and semi arid districts of Haryana like Bhiwani, Hisar and Rewari pomegranate, ber and aonla are well-suited. Sapota, and litchi cultivation is focused in the humid zones of Yamunanagar, Ambala, Panchkula (Table-3). Haryana cultivates a wide variety of vegetables and spices, with key crops like potato, tomato, onion, and cauliflower grown in districts such as Yamunanagar, Panipat, Hisar, and Ambala. Spices like garlic, turmeric, coriander, and fenugreek are concentrated in regions like Kaithal, Panchkula, and Yamunanagar, highlighting the state's crop diversity

Table 2: Top horticultural crops grown in Haryana

Crops	Area (Ha)	Production (MT)	
Fruit			
Citrus	25176.3	359083.7	
Guava	16749.94	183643.3	
Mango	7803.95	98338	
Sapota	1314.6	12688	
Aonla	1682.5	9564.1	
Vegetables			
Potato	33043.2	843230	
Cauliflower	28467.8	602632	
Onion	22804.8	542588	
Tomato	22267	475712.3	
Cucurbits	52123.9	830255.8	
Brinjal	11151	177674	
Leafy Veg.	42420.4	510531.1	
Spices			
Garlic	3702.6	30465.5	
Fenugreek	1042.6	1966.5	
Ginger	57.12 690.1	57.12 690.1	
Flower			
	Area	Production (MT)	Cut Flower(in lakh)
Marigold	1376	18907	-
Rose	56.4	276	2.13
Gladiolus	38	-	75.03
Medicinal and Aromatic Plants			
Aloevera	5.3	6.5	

Haryana: Strengths, Opportunities, and Initiatives in Horticulture

Strengths

Haryana possesses several natural and strategic advantages that make it ideal for horticultural growth:

- A favorable climate conducive to the production of high-quality fruits and vegetables.
- Fertile soils particularly suited for intensive cultivation of horticultural crops.
- Strategic location with close proximity to major markets such as Delhi-NCR and the tri-city region (Chandigarh, Panchkula, Mohali), facilitating easy access and distribution.

Opportunities

The horticulture sector in Haryana holds immense potential for expansion and value addition:

- The state's proximity to NCR presents excellent marketing and trade opportunities.

- There is significant scope for setting up processing industries for fruits like mango, citrus, and strawberry, and vegetables such as peas, tomatoes, potatoes, carrots, garlic, and onions.
- Policy reforms such as amendments to the APMC Act have opened avenues for contract farming.
- Potential for increasing exports of mangoes, kinnow, and vegetables to international markets, especially the Far East.
- A business-friendly environment supports further investment in horticulture-related industries.

Table 3: Major fruit crops growing districts

Fruit Crop	Primary Districts
Kinnow/Citrus	Sirsa, Fatehabad, Hisar, Bhiwani, Mahendergarh
Mango	Yamunanagar, Panchkula, Ambala, Kurukshetra
Guava	Almost all districts – major in Hisar, Jind,Nuh, Palwal, Sirsa , Sonepat,Yamunanagar
Pomegranate	Sirsa, Fatehabad, Charki Dadri, Mahendergarh, Palwal
Ber	Hisar, Jind, Jhajjar, Sonipat, Fatehabad, Palwal, Rohtak
Aonla	Hisar, Sirsa, Rewari, Mahendragarh, Yamunanagar, Mewat, Palwal
Papaya	Panipat, Faridabad, Palwal, Gurugram
Peach/Plum	Panchkula, Ambala, Kurukshetra,, Yamunanagar, Hisar,Sonipat
Pear	Yamunanagar, Panchkula, Kurukshetra, Ambala
Lemon	Sonipat, Nuh, Jhajjar, Gurugram
Strawberry	Bhiwani, Hisar, Sirsa, Panipat, Sonipat, Gurugram
Sapota	Ambala, Panchkula, Yamunanagar
Litchi	Ambala, Panchkula, Yamunanagar

Key Initiatives

Haryana has made remarkable strides in promoting horticulture through substantial policy and infrastructure support:

1. Focus on Protected and Vertical Cultivation

Greenhouse technology is playing a crucial role in promoting disease-free nurseries, off-season and pesticide-free vegetable cultivation, with government support providing 50% subsidy for general farmers and up to 85% for S.C. farmers, covering 2,497 hectares under protected and vertical farming methods like bamboo stacking.

2. Mera Pani Meri Virasat

A holistic new program has been launched to promote diversification into orchards, vegetables, and spices by targeting paddy and other cereal crop areas, integrating advanced practices like hi-tech horticulture, vertical farming, and integrated farming systems.

3. Major Projects

A. **JAPAN INTERNATIONAL CORPORATION AGENCY (JICA) Project:** The Government of Haryana has approved "The Project for Promoting Sustainable Horticulture in Haryana" under JICA ODA (Official Development Assistance). This project shall help in the establishment of 53 complete supply chain in horticulture in Haryana with technological interventions both at forward and backward level and it will usher a new era in Haryana.

B. Post-Harvest & Value Chain Development

A Centre of Excellence for Post-Harvest Management has been established in collaboration with the University of Birmingham to demonstrate modern cold storage, supply chain systems, and value addition technologies. Start-up incubation and applied research are also key components.

4. Beekeeping & Honey Promotion

To enhance honey quality and trade, a Honey Quality Control Lab and Honey Trade Centre have been set up, aimed at improving income and market opportunities for beekeepers.

5. Seed Potato Advancement

Under the Potato Policy-2022, Haryana is scaling up seed potato production using tissue culture and advanced techniques like aeroponics, with support from specialized centres and certified farmer fields.

6. Centres of Excellence for Crop-Specific Support

New Centres of Excellence have been established, including one for semi-arid horticultural crops in Bhiwani focusing on date palm, strawberry, and exotic crops, and another upcoming for onion in Nuh to boost kharif onion production and seed supply.

7. Farmer Insurance & Price Support

Schemes like Mukhyamantri Bagwani Bima Yojana (MBBY) and Bhavantar Bharpayee Yojana (BBY) provide risk coverage and price support to horticulture farmers, encouraging crop diversification and stability in income.

8. **Quality Control Infrastructure**
   Two pesticide residue testing labs have been set up to ensure produce quality and safety. These labs analyze soil, water, and crop samples to support high-standard production.

9. **Crop Cluster Development Programme (CCDP)**
   The CCDP focuses on building cluster-based infrastructure such as pack houses, processing centres, grading units, and storage to strengthen market linkages and post-harvest value.

10. **Digital Outreach & Farmer Services**
    The department uses social media and the HORTNET portal to connect with farmers, share updates on policies, schemes, and training. Services like online seedling booking (Hortsalenet), a dedicated horticulture helpline, and e-office integration ensure accessible and transparent support.

11. Introduction of national schemes such as the National Horticulture Mission, Micro-Irrigation Mission, and National Mission on Medicinal Plants. These focus on expanding fruit, flower, and spice cultivation, creating water resources like community tanks, and strengthening post-harvest infrastructure.

12. Expansion of training and capacity-building at the Horticulture Training Institute in Karnal, and various center of excellence.

13. Advancement in biotechnology, including the production of micro-tubers in potatoes and the introduction of new varieties through tissue culture.

Constraints

1. Water & Irrigation Constraints

- Rapid depletion of groundwater, especially in central and southern Haryana
- Over-dependence on borewells with unregulated extraction
- Low adoption of micro-irrigation (drip/sprinkler systems)
- Poor water use efficiency and absence of water harvesting structures
- Inadequate canal irrigation in fruit-growing zones

2. Agronomic & Production Constraints

- Climate stress: heat waves, untimely rainfall, and frost affecting yields
- High cost of quality planting material, fertilizers, and inputs
- Lack of skilled manpower for protected cultivation and high-tech practices
- Pest and disease infestations, especially in fruits and vegetables
- Limited adoption of improved varieties and post-harvest techniques

Table 4: Major Vegetables crops growing district

Vegetable crops/ Spices	**Primary Districts**
Potato	Yamunanagar,Karnal, Panipat Ambala, Kurukshetra
Tomato	Mewat, Yamunnagar, Panipat, Bhiwani, Jind
Onion	Almost all districts – Ambala, Yamunagar,Nuh, Panipat
Radish	Yamunagar, Ambala,Fatehabad, Hisar
Carrot	Hisar, Jind, Ambala
Cabbage	Hisar, Jind, Nuh, Panipat, Sonipat, Yaamunnagar
Cauliflower	Ambala, Fatehabad, Hisar, Panipat, Yamunnagar, Kurukshetra
Chilli/ Capsicum	Bhiwani, Hisar, Jind, Panipat Kurukshetra, Ambala Karnal, Panipat
Cucurbitaceous	Bhiwani, Karnal, Palwal,Panipat, Yamunnagar
Bhindi	Nuh, Ambala, Panipat, Yamunnagar
Peas	Kurukshetra, Mahendergarh, Panipat, Rewari
Garlic	Kaithal, Karnal,Yamunanagar, Palwal
Turmeric	Panchkula, Yamunanagar
Ginger	Panchkula
Coriander	Kaithal. Jhajjar, Yamunanagar
Fenugreek	Jhajjar, Kaithal, Rewari , Yamunanagar

3. Infrastructure & Marketing Constraints

- Inadequate cold storage and packhouse infrastructure
- Poor rural road connectivity affecting timely transportation
- High post-harvest losses due to lack of grading, sorting, and processing
- Price fluctuations and weak market intelligence systems

- Dependency on middlemen; limited access to direct markets

4. Socioeconomic & Adoption Barriers

- Reluctance to shift from traditional wheat-paddy cropping system
- Small landholdings limiting investment in high-value horticulture
- Low farmer awareness of modern practices and export potential
- Women and small farmers face more challenges in accessing credit and schemes
- Risk aversion due to lack of crop insurance and extension services

Conclusion

Haryana’s horticulture sector is evolving into a key driver of agricultural transformation, offering promising opportunities for income enhancement, sustainability, and nutritional security. Despite facing constraints related to water, infrastructure, and adoption, the state is making notable progress through focused initiatives and policy support. With continued investment in technology, market access, and farmer capacity-building, Haryana is well-positioned to emerge as a leading hub for high-value horticultural production. Strategic interventions and collaborative efforts will be crucial in realizing its full potential.