ISSN : 2582-6344
Volume - 6, Issue -2

Times of Agriculture

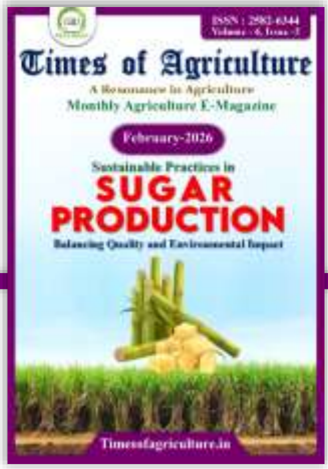
A Resonance in Agriculture

Monthly Agriculture E-Magazine

February-2026

Sustainable Practices in SUGAR PRODUCTION

Balancing Quality and Environmental Impact



Times of Agriculture

A Resonance in Agriculture

ISSN No.: 2582-6344
Frequency: Monthly
Month: February
Volume- 6, **Issue**- 2
Pages in Magazine- 32

Timesofagriculture.in

From the Editor's Desk

Dear Readers,

Greetings to all the esteemed readers of **Times of Agriculture Magazine**. The theme of this issue is focused on Environmental Balance along with **Sugar Production**. As we all know, India is continuously progressing in sugar production and is marking its strong presence at the global level. This achievement is the result of the hard work of our diligent sugarcane producing farmers.

However, along with increasing production, maintaining environmental balance is equally necessary. Sugarcane is a water-based crop and at present excessive use of pesticides and chemical fertilizers is being carried out in it. In such a situation, it becomes necessary that farmer brothers use these resources in a balanced and scientific manner, so that there is no adverse effect on soil fertility, water resources, and the ecosystem.

Our farmers need to adopt drip irrigation systems along with using fertilizers and pesticides in regular and disciplined quantities, so that water can be conserved and better production can be achieved. In addition, by adopting sustainable measures such as integrated nutrient management, use of bio-fertilizers, crop residue management, and recycling of by-products like press mud and biogas, environmental balance can be established on a large scale.

Today, it is the demand of the time that farmer brothers adopt modern agricultural technologies and give equal importance to environmental protection along with production growth. Sustainable agriculture is the direction of the future.

Let us, through this issue, obtain accurate information about these new and useful technologies and spread the message of awareness to more and more farmers.

Thank you.

Enjoy Reading!

Editor-In-Chief


Times of Agriculture
Monthly Agriculture e-Magazine
February-2026
Sustainable Practices in
SUGAR
PRODUCTION
Balancing Quality and Environmental Impact
Times of Agriculture
A Resonance in Agriculture
Monthly Agriculture E-Magazine
February-2025
Timesofagriculture.in

CONTENT

Times of Agriculture
A Resonance in Agriculture

AGRICULTURE UPDATES

Government Launches Bharat-VISTAAR to Transform Farm Advisory with AI

The Centre has launched Bharat-VISTAAR (Virtually Integrated System to Access Agricultural Resources), a multilingual artificial intelligence platform designed to transform farm advisory services and strengthen decision-making at the grassroots level. Announced in the Union Budget by Finance Minister Nirmala Sitharaman, the initiative seeks to integrate key agricultural databases and digital services into a unified system accessible to farmers across the country. The platform brings together the government's AgriStack portals with scientific crop practice packages developed by the Indian Council of Agricultural Research, combining them with AI capabilities to generate customised, real-time advisories. Officials said the move is aimed at enhancing farm productivity, improving risk management, and ensuring more efficient use of resources such as water, fertilisers and agro-chemicals.

The formal launch was carried out by Union Agriculture Minister Shivraj Singh Chouhan at an event in Jaipur, where he described the platform as a milestone in India's digital agriculture journey. Bharat-VISTAAR is designed to function in more than 20 Indian languages and dialects, enabling farmers to access information through voice-based and mobile interfaces. By analysing data related to soil health, weather forecasts, crop patterns, pest outbreaks and market prices, the system delivers field-specific recommendations tailored to individual needs. The multilingual AI engine is expected to bridge gaps caused by literacy barriers and limited access to extension services, particularly for small and marginal farmers in remote regions.

Bharat-VISTAAR will support the wider adoption of precision farming technologies across geographies and crop varieties. By consolidating fragmented advisory channels into a single digital ecosystem, the platform aims to empower cultivators with timely insights that can improve crop yield and nutritional outcomes while reducing input costs. The initiative is also expected to strengthen coordination between central and state agricultural departments, research institutions and on-ground extension workers.

Amazon Partners IIT Roorkee to Develop Biodegradable Mailers from Crop Waste

In a significant push toward sustainable packaging, Amazon has partnered with the Indian Institute of Technology Roorkee to develop biodegradable paper mailers made from agricultural residue. The 15-month pilot research project will focus on converting crop waste such as wheat straw and sugarcane bagasse into eco-friendly e-commerce packaging solutions. The collaboration aims to address the dual environmental challenges of plastic packaging pollution and the heavy dependence on virgin wood pulp, which remains the primary raw material used in conventional paper mailers.

According to Abhinav Singh, Vice President of Operations at Amazon India, the company is committed to building one of the country's fastest and most reliable operations networks while making it more environmentally responsible. He noted that India generates nearly 500 million tonnes of agricultural residue annually, much of which remains underutilized or is burned, contributing to pollution. By repurposing this biomass into packaging materials, the partnership aims to promote a circular economy model that reduces waste and lowers dependence on traditional forest-based resources. The project also aligns with Amazon's broader sustainability goals of reducing single-use plastics and improving packaging efficiency across its logistics network. The research and development work will be carried out at the Innovations in Paper and Packaging Lab under the Department of Paper and Packaging Technology at IIT Roorkee. During the pilot phase, crop residues such as wheat straw and bagasse will be processed into pulp using an autoclave digester. The pulp will then be washed and screened to remove impurities, ensuring consistent quality before undergoing drying and pressing to produce paper suitable for durable e-commerce mailers. Following successful lab-scale testing, Amazon will support industrial trials, process validation and eventual commercial production, with large-scale rollout targeted for mid to late 2027.

John Deere Unveils MY27 Sprayer Upgrades with Advanced See & Spray Gen 2 Technology

Agricultural equipment giant John Deere has announced its Model Year 2027 (MY27) updates for its sprayer lineup, introducing the next-generation See & Spray Gen 2 system alongside enhanced maneuverability and upgraded digital integration. The latest advancements are designed to improve operational efficiency, reduce chemical usage, and expand crop compatibility for farmers worldwide. A major highlight is the expanded See & Spray Gen 2 technology, which now supports additional crops such as wheat, canola, and sugar beets. The system incorporates higher-quality cameras, consolidated and faster-processing units, and new night-time spraying capabilities.

Another key upgrade is the introduction of four-wheel steering on John Deere's 400-series sprayers. This feature enhances headland management and reduces crop damage during tight turns, while also offering a "crab steer" option for better maneuverability across challenging terrain. The company has also strengthened its precision agriculture ecosystem with improved Exact Inject direct chemical injection technology for more accurate chemical management. Upgraded G5Plus displays deliver faster processing speeds and smoother user interaction, while deeper integration with the John Deere Operations Center enables better data management and real-time decision-making for farm operators.

In addition to new-machine enhancements, John Deere is offering retrofit options to make See & Spray Gen 2 accessible to existing customers. The technology can be installed on 2018 and newer sprayer models using a dedicated "puck" kit, expanding adoption without requiring a full equipment replacement. Enhanced visibility features, including new center-frame cameras designed to improve detection accuracy and minimize dust interference, will be available across 400 and 600 series machines as well as Hagie sprayers.

India Launches Nationwide Pulses Revolution with Self-Reliance Mission

A new chapter in India's pulses policy and farmer-centric agricultural strategy was inaugurated at the Food Legumes Research Centre (FLRP) in Amlaha, located in Sehore district of Madhya Pradesh. The nationwide pulses revolution was formally launched under the chairmanship of Union Minister for Agriculture & Farmers' Welfare and Rural Development, Shivraj Singh Chouhan. During the event, the roadmap for the ambitious 'Self-Reliance in Pulses Mission' was finalized, signaling a decisive push toward reducing India's dependence on imports and strengthening domestic production of key food legumes.

Addressing concerns raised by sections of the opposition regarding recent international trade agreements, Chouhan firmly dismissed apprehensions that farmers' interests would be compromised. He asserted that importing pulses is a matter of concern for a country with vast agricultural potential and declared that India is determined to transform from an importer into an exporter of pulses. The minister emphasized that the government would not allow even the slightest adverse impact on farmers due to global agreements. He described the current policy direction as historic and transformative, aimed at enhancing self-sufficiency while ensuring stable and remunerative returns for cultivators.

Chouhan further stated that the broader agricultural trade strategy would open new avenues for India's economic progress. Increased exports of spices and rice, along with safeguards for dairy products, are expected to generate employment opportunities and strengthen rural incomes. By boosting pulses production through research support, improved seed varieties, and assured procurement mechanisms, the government aims to enhance nutritional security while empowering farmers. The launch of the Self-Reliance in Pulses Mission from FLRP Amlaha underscores a renewed policy focus on value addition, export competitiveness, and long-term sustainability in India's agricultural sector.

NITI Aayog Study Calls for Strategic Reforms to Align Agriculture with Net Zero Goals

NITI Aayog has released a comprehensive study titled *Scenarios Towards Viksit Bharat and Net Zero*, outlining a roadmap for transforming India's agriculture sector through sustainable and climate-resilient practices. The report underscores the importance of "strategic sequencing," a phased and carefully planned transition in farming systems that balances productivity with environmental responsibility. It emphasizes that reforms must be gradual yet decisive, ensuring that efficiency gains are achieved without disrupting farmer livelihoods. By aligning agricultural growth with India's long-term climate commitments, the study positions sustainability at the core of rural development policy.

The report highlights several resource-efficient interventions to curb emissions and enhance productivity. These include scaling up micro-irrigation systems, optimizing fertilizer use to reduce nitrous oxide emissions, and expanding solar-powered irrigation infrastructure to cut dependence on conventional electricity. According to the findings, agriculture accounts for nearly 14 percent of India's total greenhouse gas emissions, largely due to methane released from livestock and paddy cultivation, as well as nitrous oxide emissions from excessive fertilizer application. In addition, the sector consumes around 18 percent of the country's electricity, primarily for groundwater pumping and mechanized farm operations, intensifying both energy demand and indirect carbon emissions.

Under the Current Policy Scenario (CPS), agricultural emissions are projected to rise from 506 million tonnes of carbon dioxide equivalent ($MtCO_2e$) in 2019 to 531 $MtCO_2e$ by 2070. This upward trajectory highlights the urgency of adopting low-carbon technologies and sustainable farming models. The report calls for integrated policy support, technological innovation, and farmer incentives to accelerate the transition. By promoting efficient water management, renewable energy use, and improved nutrient practices, the study argues that India can simultaneously safeguard food security, enhance farm incomes, and advance toward its net-zero ambitions while building a resilient and climate-smart agricultural system.

Government Launches White Revolution 2.0 to Boost Dairy Cooperatives and Milk Procurement

The Government of India has unveiled White Revolution 2.0, an ambitious initiative aimed at strengthening the country's dairy sector through a cooperative-driven framework. The programme seeks to increase milk procurement by dairy cooperatives by 50 percent over the next five years, with a daily procurement target of 1,007 lakh kilograms by 2028–29. The move is designed to reinforce India's position as the world's largest milk producer while ensuring that growth in the sector directly benefits small and marginal farmers. White Revolution 2.0 builds upon the legacy of Operation Flood, spearheaded by Verghese Kurien under the National Dairy Development Board, which transformed India from a milk-deficient nation into a global dairy leader.

The new initiative places strong emphasis on expanding the cooperative network into villages that remain outside the organized dairy ecosystem, while also strengthening existing institutions. By improving procurement systems, enhancing market access, and modernizing infrastructure, the government aims to raise incomes for millions of rural households dependent on dairying. A key objective is to increase the cooperative sector's share within the organized dairy industry, ensuring fair price realization for farmers and reducing the role of intermediaries. Officials note that dairying remains a critical supplementary income source for smallholders and landless households, particularly women, thereby contributing to inclusive rural development.

White Revolution 2.0 adopts a dual expansion strategy to accelerate impact. Nearly 75,000 new Dairy Cooperative Societies (DCS) will be established in uncovered panchayats and villages, widening the procurement base. Simultaneously, about 46,422 existing DCSs will be strengthened through improved operational efficiency, upgraded chilling and storage facilities, and stronger market linkages. Beyond income enhancement, the programme also underscores nutritional security, recognizing milk as a vital source of protein, calcium, and essential micronutrients. Through cooperative empowerment and infrastructure modernization, the government aims to drive sustainable growth in the dairy sector while improving livelihoods and food security nationwide.

COVER STORY

Sustainable Practices in SUGAR PRODUCTION

Balancing Quality and Environmental Impact

About the Author

Alok Saxena

Executive Director and Unit Head – Sugar

Power & Ethanol Division of Zuari Industries

The Indian sugar sector, recognized as the world's second-largest sugar producer and the largest consumer, stands at a decisive juncture. For the 2025–26 marketing year, government first advance estimates indicate that sugarcane production may reach **around 475.6 million metric tonnes**, up from **405.4 million metric tonnes in 2020–21**. This steady rise over five years reflects the sector's scale and resilience.

However, growth is no longer judged only by output volumes. With India's commitment to achieving **Net Zero emissions by 2070**, and the early progress made under the **20% Ethanol Blending Programme (E20)**, the sugar industry has evolved into a more integrated bio-refinery ecosystem. Sustainability today requires that every quintal of cane processed delivers multiple outcomes: **consistent, high-quality sugar, reduced environmental impact, and meaningful support to rural livelihoods**.

The Development of the Integrated Bio-Refinery Framework

The Indian sugar industry has moved well beyond conventional milling. Modern sugar mills now operate as **integrated bio-refineries**, where circular-economy principles are embedded into daily operations. Bagasse, molasses, press mud, and other by-products are no longer treated as waste but as valuable inputs within a tightly managed system.

The **Sugar (Control) Order, 2025** marks an important regulatory shift by extending oversight beyond sugar to include **bagasse, molasses, press mud, and ethanol**. This expanded framework supports optimal utilisation of every tonne of cane, while ensuring that diversion towards green energy does not compromise domestic sugar availability.

Widespread adoption of **bagasse-based cogeneration** has significantly reduced dependence on fossil fuels, lowering the carbon footprint of sugar manufacturing, particularly for thermal energy requirements. In parallel, the integration of modern distilleries has reshaped the industry's financial structure. The government's policy of diverting surplus sugar towards ethanol has helped stabilize domestic sugar prices and reduce crude oil imports, resulting in **foreign exchange savings estimated at over ₹1.4 lakh crore during the past decade**.

The calibrated transition towards **B-heavy molasses and direct sugarcane juice for ethanol** has enabled higher biofuel production while maintaining internationally acceptable quality standards for crystallized sugar.

Varietal Innovation and Precision Agriculture

Sustainability in the sugar industry begins at the farm gate. Maintaining strong recovery rates, which directly influence both product quality and mill viability, has required sustained investment in **varietal development and climate resilience**.

In northern India, particularly **Uttar Pradesh**, which contributes the largest share of national sugarcane production, there has been a conscious shift towards **high-sucrose, stress-tolerant varieties**. These cultivars are designed to deliver improved **Commercial Cane Sugar (CCS)** levels even under water-stressed conditions, ensuring consistent quality of cane supplied to mills.

Precision agriculture has further strengthened environmental performance. The adoption of **drip irrigation systems** has demonstrated water savings of **up to 40–50%** compared to conventional flood irrigation under suitable field conditions. Supporting this transition, the Sugar (Control) Order, 2025 provides for **digital integration between the Department of Food and Public Distribution (DFPD) portal and sugar mill ERP/SAP systems**. More than **450 sugar mills** are already integrated, enabling real-time data sharing.

This digital backbone helps ensure that quality begins with informed decisions on soil health, water use, and agronomic practices, directly influencing the livelihoods of **around five crore farmers** dependent on sugarcane cultivation.

India's Sugar Industry at a Turning Point

Promoting Environmental Standards through Technological Innovation

Technological change within factory operations has been equally significant. An increasing number of Indian sugar mills are implementing **Zero Liquid Discharge (ZLD)** systems to manage process water and distillery effluents responsibly.

Spent wash, once considered a major environmental challenge, is now increasingly managed through **Multi-Effect Evaporators (MEE)** and incineration boilers. These systems allow recovery and reuse of water in cooling towers and boilers, while the residual ash, rich in potash, is returned to agriculture as an organic soil nutrient.

The Sugar (Control) Order, 2025 further extends regulatory oversight to **khandsari units with capacities above 500 TCD**, bringing **66 large units** within the formal regulatory framework. This expansion strengthens enforcement of environmental and quality standards across the sector. Inclusion of unrefined sugar in official stock accounting also improves traceability and transparency, reducing mislabelling risks and reinforcing the integrity of Indian sugar in domestic and export markets.

Social Sustainability and International Quality Standards Compliance

A truly sustainable industry must also be socially balanced. In India, the sugar sector remains a critical driver of rural employment and income security. Recognising this, the government has approved a **Fair and Remunerative Price (FRP) of ₹355 per quintal for the 2025–26 season**, linked to a **10.25% recovery rate**, representing an increase over the previous year.

Balancing Quality, Environment & Economy

At this level, the FRP remains significantly higher than estimated **A2+FL production costs**, providing reasonable assurance of farmer viability. Improved liquidity from ethanol revenues and policy support has also strengthened payment discipline. Official data indicates that **nearly all cane dues from previous seasons have been cleared**, with timely payments improving across most producing states.

On the quality front, Indian sugar manufacturers are aligning with updated **FSSAI standards** for refined sugar, plantation white sugar, and cube sugar, while pursuing international certifications required by premium export markets. These standards are increasingly essential as global buyers demand evidence of ethical sourcing, environmental compliance, and consistent product quality.

Strategic Direction from 2026 Onward

The long-term competitiveness of the Indian sugar industry will depend on how effectively it aligns **product quality with environmental performance**. The Government of India's move towards a more unified, digitally enabled regulatory framework, supported by real-time supply-chain data, is laying the foundation for a resilient and globally competitive bio-economy.

Sustainability is no longer optional. It has become a strategic necessity. By integrating renewable energy, precision agriculture, responsible water management, and robust quality standards, the Indian sugar industry has demonstrated that scale and sustainability can progress together.

As the 2025–26 season unfolds, India's sugar sector stands as a credible example of how a traditional agro-industry can transition into a modern, technology-driven contributor to renewable energy, nutrition, and rural development, without compromising on quality or environmental responsibility.

****

BIOFORTIFIED SEEDS AS A POLICY PRIORITY

WHAT BUDGET 2026 SIGNALS FOR NUTRITION, HEALTH AND FARMER INCOME

About Author

Mr. Prateek Rastogi

Co-Founder & CEO of Better Nutrition

While presenting Budget 2026, the finance minister made a critical observation that deserves far more attention than it received. India's burden of non-communicable diseases is rising sharply, and healthcare costs linked to lifestyle and nutrition-related conditions are becoming unsustainable.

This is not just a health problem. It is a food problem. And at its core, it is an agricultural problem. For decades, India focused on feeding its population and that mission succeeded. Today, the challenge has changed. We are producing enough food, yet iron deficiency, anaemia, zinc deficiency, poor bone health, and low immunity affect large sections of the population - including urban families eating regular home-cooked meals.

Budget 2026 reflects early recognition of this shift. There is greater emphasis on value-added agriculture, seed innovation, and nutrition-linked outcomes. But acknowledgement alone will not reverse decades of nutritional dilution in our food system.

The real question is: how does nutrition actually reach the plate, every day, at scale?

The nutrition problem starts before the kitchen

India's nutrition crisis does not begin with poor food choices. It begins much earlier in the soil and in the seed.

Over years of yield focused farming, soil micronutrients have been depleted. Crop varieties were bred to grow faster and produce more, not necessarily to nourish better. The result is food that looks the same, cooks the same, but delivers fewer essential minerals like iron, zinc, calcium, and magnesium. To compensate, we built downstream fixes - supplements, fortified additives, powders, gummies. These play a role in medical settings, but as a population-wide solution, they are expensive, inconsistent, and hard to sustain. Food, however, is eaten every single day. If nutrition can be built into the grain itself, quietly and naturally, dependency on constant supplementation reduces. No habit change. No extra step. No pill fatigue.

Why biofortified seeds deserve policy attention

Biofortification is often misunderstood because of how technical it sounds. In reality, it is deeply practical. When seeds are developed to absorb and retain higher levels of micronutrients and when soil practices support this uptake the grain itself becomes more nutritious. No chemical addition. No artificial enrichment after harvest.

India already has strong scientific foundations in this space. Public research bodies like ICAR, global institutions such as CIMMYT, nutrition science leaders like NIN, and international programmes including HarvestPlus have all contributed to developing and validating biofortified crop varieties. Science exists. The seeds exist. What hasn't scaled yet is adoption by farmers and by consumers.

From policy to practice: adoption is the missing link

The Year of Millets showed what happens when policy intent, awareness, and market access align. Millets moved from niche to mainstream not because they were new, but because people finally understood why they mattered and where to find them. Biofortified crops now need a similar push. Farmers adopt faster when there is assured demand and better price realization. Consumers shift behaviour when nutrition is simple, familiar, and trustworthy. This is where brands play a critical role.

Healthy Atta Is Not About Additions. It's About Origins

Today, many food brands are responding to nutrition concerns by adding protein, minerals, or vitamins into finished products. Protein-enriched biscuits, fortified chocolates, and supplements are everywhere. But nutrition added at the end is not the same as nutrition grown at the start.

A genuinely healthy atta does not rely on heavy formulation. It begins with better seeds, healthier soil, and transparent validation. When wheat itself is richer in iron, zinc, and minerals, the atta made from it delivers nutrition naturally without changing taste, texture, or digestion.

This approach also avoids forcing consumers into new habits. Rotis remain rotis. Meals remain familiar. Only the nutritional value improves.

Biofortified foods are already a reality

One important shift over the last few years is that biofortified foods are no longer confined to research plots or pilot projects.

Today, staples like biofortified atta and rice grown using better seed and soil practices and tested for nutritional density are already available to consumers. These products are being adopted across major retail and quick-commerce platforms such as Blinkit, Swiggy Instamart, Zepto, Amazon, and others. This matters because it proves something critical: nutrition-led agriculture can scale through mainstream supply chains, not just government programmes.

What budget 2026 can enable next:

If biofortified seeds are to become a true policy priority, the next phase must focus on:

- Encouraging farmer adoption through clear market signals.
- Supporting consumer awareness around food quality, not just quantity.
- Enabling traceability and validation so nutrition claims are credible.

India spends thousands of crores each year managing diseases that stem from poor nutrition. The more sustainable solution lies upstream in making food itself more nourishing. Budget 2026 has opened the door by acknowledging nutrition as part of agriculture's future. The opportunity now is to push adoption so nutrition is no longer treated as a supplement problem, but as a farm-level outcome. Biofortified foods are not a distant idea. They are already here. The task ahead is to make them the default choice starting with the everyday staples on every Indian plate.

FROM FLOOD TO FINE-TUNE

HOW PRECISION IRRIGATION IS REVOLUTIONIZING INDIAN FARMS

About Author

Gantla Srikanth Reddy
Chief Manager, Research

State Bank Institute of Rural Development
State Bank of India

India stands at a critical hydrological crossroads. According to the Ministry of Jal Shakti (2025), while India supports approximately 18% of the world's population, it possesses only 4% of the global renewable water resources. The NITI Aayog Water Index warns that per capita water availability has plummeted from 1,816 cubic meters in 2001 to a projected 1,445 cubic meters by 2025, pushing the nation toward "absolute scarcity" (defined as <1,000 cubic meters).

Agriculture, the backbone of the Indian economy, consumes nearly 80-90% of this dwindling resource. Traditional flood irrigation methods, characterized by massive conveyance losses and evaporation, are no longer tenable for a nation aiming for a $5 trillion economy. To ensure food security for 1.4 billion people, an Integrated Water Resources Management (IWRM) approach is imperative. This strategy combines in-situ water conservation—such as rainwater harvesting and aquifer recharge—with Precision Irrigation (PI). PI is not merely a technical upgrade; it is a foundational shift toward sustainable intensification, ensuring every drop of water contributes to caloric and economic value.

Defining precision irrigation

Precision irrigation is a data-driven agricultural management system that ensures the delivery of the right amount of water, at the right time, and at the right location (the plant's root zone). Unlike traditional methods that treat entire fields uniformly, precision irrigation utilizes sensors, automation, and site-specific data to optimize water productivity and minimize waste.

The existing irrigation landscape

Source	Usage	Characteristics
Tube & Bore wells	46.90%	Primary source; facing severe over-exploitation in India
Canals	24.70%	Surface water reliant; high conveyance losses.
Open Wells	12.20%	Traditional; highly sensitive to seasonal rainfall.
Tanks & Ponds	2.80%	Critical in South India; undergoing rejuvenation via *Jal Shakti Abhiyan*
Precision irrigation	13.40%	Emerging; includes drip and sprinkler irrigation.

(Source: National Water Mission Survey-2024, Ministry of Jal Shakti)

Groundwater from tube and bore wells remains the primary irrigation source but is critically over-exploited across India. Canals still supply major surface water despite high losses, while open wells depend on monsoon rains. Tanks and ponds in South India are being revived, and Precision Irrigation is rapidly expanding.

The necessity for precision irrigation

With nearly 43.6% of India's cultivated area still rain-fed, the vulnerability to climate change is immense. Precision techniques are no longer a luxury for the elite farmer; they are a survival necessity to mitigate groundwater depletion, reduce energy costs for pumping, and stabilize yields during erratic monsoons.

The architecture of precision irrigation: modern techniques

A. Advanced water delivery systems

Precision irrigation utilizes specialized hardware to deliver water directly to plant roots, minimizing losses from evaporation and runoff.

i. Drip irrigation (Surface and Subsurface)

Drip irrigation is the most water-efficient delivery method, achieving application efficiencies of 85–95%.

- **Surface drip:** Delivers water and nutrients (fertigation) directly to the plant root zone through a network of pipes and emitters.
- **Subsurface Drip Irrigation (SDI):** Places laterals 15–45 cm below the soil surface to virtually eliminate evaporation, reduce weed growth, and protect equipment from mechanical damage.
- **Impact:** Drip systems can save 50–65% of water compared to traditional methods while increasing yields by 20–40%.

ii. Precision sprinkler systems

Sprinkler systems simulate natural rainfall through pressurized nozzles and are highly adaptable to varied terrains.

- **Micro-sprinklers:** Ideal for orchards and closely spaced crops, these provide localized coverage and help manage the microclimate through fine mist cooling.
- **Center Pivot and Linear Move:** Large-scale automated systems that utilize Variable Rate Irrigation (VRI) to adjust water flow based on GPS-linked moisture maps.

The water use efficiency by using drip and sprinklers irrigation

Crop	Water Saving (%)	Yield Increase (%)	WUE Increase (%)
Sugarcane	46 - 56	33 - 46	204
Banana	45 - 46	16 - 52	176
Grapes	37 - 48	23	136
Sweet Lime	61	50	289
Pomegranate	45	98	167
Tomato	31 - 40	35 - 50	119
Water Melon	36	88	196
Chilies	63	44	291
Cotton	37 - 40	25 - 30	121
Wheat	29	14 - 20	115
Mango	64	82	>500

(Source: Indian Council of Agricultural Research Data-2024)

iii. Specialized protected cultivation techniques

In greenhouses and soilless systems, precision is refined through specialized mechanisms:

- **Capillary mats and wicks:** Thin, porous materials use capillary action to deliver moisture from a reservoir directly to the roots of potted plants without electricity.
- **Hydroponic systems:** Techniques like the Nutrient Film Technique (NFT) and Aeroponics provide an optimal supply of water and nutrients, resulting in faster growth and higher yields compared to soil-based farming.

B. Monitoring and sensing technologies

Accurate data allows farmers to move from fixed schedules to irrigation based on actual plant needs.

i. Soil-based monitoring

Sensors measure the moisture status of the soil to trigger automated irrigation.

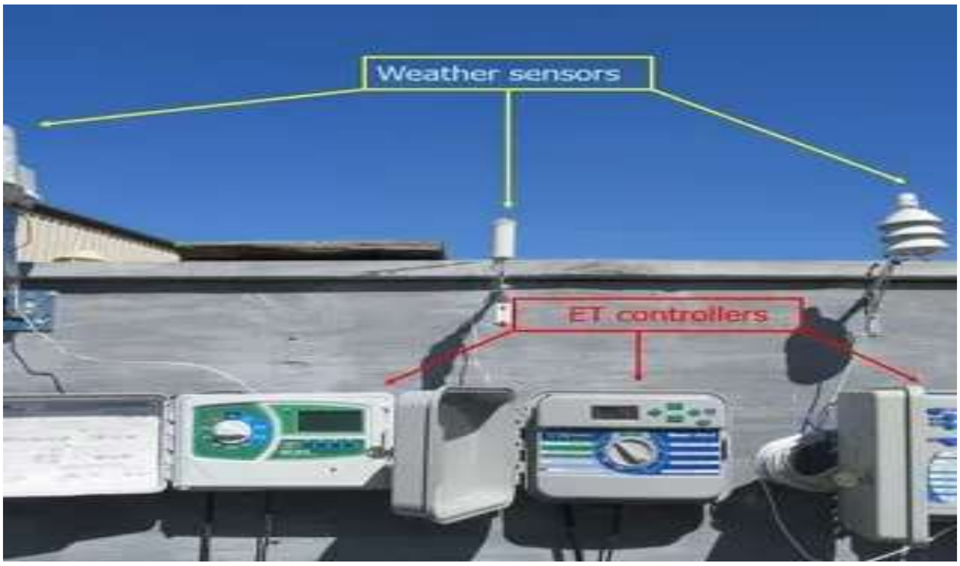
- **Tensiometers:** Measure the force roots must use to extract water, offering a direct indicator of moisture availability.
- **Capacitance and TDR Sensors:** These electronic devices detect changes in the soil's dielectric properties to determine volumetric water content in real-time.

ii. Plant-based sensing

Direct monitoring provides physiological insights into a crop's hydration state.

- **Sap Flow Sensors:** Measure the movement of water through the plant stem to quantify actual transpiration.
- **Dendrometers:** Monitor micro-variations in stem diameter; rapid shrinkage is a sensitive early indicator of water stress.
- **Thermal Sensors:** Use infrared technology to detect canopy temperature increases


Specialized protected cultivation techniques



that signal thirst before visible symptoms appear.

C. Integrated control and digital management

Modern systems integrate delivery hardware with digital decision-support platforms to automate farm management.

i. Smart irrigation controllers:

- **Weather-Based (WBICs):** Use real-time meteorological data like temperature and humidity to calculate daily water requirements.
- **Sensor-based:** Create closed-loop systems that automatically start or stop pumps based on predefined moisture thresholds.

ii. IoT and cloud integration:

Wireless sensor networks aggregate field data, allowing farmers to monitor moisture levels and control pumps remotely via mobile apps.

iii. Remote sensing:

Drones and satellites provide high-resolution multispectral imagery to compute vegetation indices like Normalized Difference Vegetation Index (NDVI), identifying stress patterns across large farms to guide precision application.

D. Summary of irrigation performance

The following table compares the efficiency and impact of various precision techniques against traditional methods.

Irrigation Method	Application Efficiency (%)	Water Savings (%)	Yield Increase (%)
Surface Flooding	30-40	Base-line	Base-line
Sprinkler System	65-75	30-40	15-25
Drip Irrigation	85-95	50-65	20-40
Micro-sprinkler	70-85	35-50	15-30
Subsurface Drip	90-95	55-70	25-45

Challenges

- **Financial barriers:** High initial capital requirements, ranging from ₹50,000 to ₹150,000 per hectare, often deter farmers who lack access to institutional credit.
- **Land fragmentation:** National land holdings average just 1.08 hectares; these
- **Knowledge gaps:** A lack of technical expertise frequently leads to improper system operation or inadequate maintenance.
- **Infrastructure deficits:** Erratic rural electricity supply and poor water quality can negatively affect system performance and shorten equipment lifespan.

Precision irrigation's water and environmental productivity assessment

- **Water Productivity (WP):** Precision systems can achieve WP values of 0.8–1.5 kg/m³ for cereals and up to 8.0 kg/m³ for vegetables, compared to much lower values under traditional flooding.
- **Economic returns:** Optimized management can yield monetary returns ranging from ₹20 to ₹100 per cubic meter of water used.
- **Environmental protection:** Precision application minimizes nitrate leaching into groundwater and reduces surface runoff, which protects soil from erosion.
- **Carbon footprint:** Carbon assessments indicate a 30-50% reduction in emissions compared to flood irrigation, largely due to reduced energy requirements for pumping.

Water productivity improvements through precision irrigation

Crop Category	Traditional WP (kg/m^3)	Precision WP (kg/m^3)	Improvement (%)	Water Saved (m^3/ha)	Additional Income (₹/ha)
Cereals	0.4–0.6	0.8–1.5	100–150%	3,000–5,000	20,000–40,000
Pulses	0.3–0.5	0.6–1.0	100–120%	1,500–2,500	15,000–30,000
Oilseeds	0.2–0.4	0.5–0.8	150–200%	2,000–3,000	25,000–45,000
Vegetables	2.0–4.0	4.0–8.0	100–120%	2,500–4,000	50,000–150,000
Fruits	1.5–3.0	3.0–6.0	100–120%	4,000–6,000	100,000–300,000
Sugarcane	5.0–8.0	10.0–15.0	100–125%	6,000–10,000	40,000–80,000
Cotton	0.15–0.25	0.35–0.50	133–150%	2,500–3,500	30,000–60,000

(Source: Ministry of Jal Shakti – Bureau of Water Use Efficiency Report)

Case studies and success stories of precision irrigation in India

Real-world deployments across India demonstrate the technical robustness and economic viability of precision irrigation systems, while the country's highly varied agro-climatic zones demand location-specific design, scheduling, and management strategies for their effective adoption.

- **Maharashtra's Drip Revolution:** In the Jalgaon district, farmers transitioning from furrow to drip irrigation in sugarcane reported water savings of 45–55% and yield increases of 25–35%. This was supported by contract farming models providing technical and financial assistance.
- **Punjab's Tensiometer Network:** To address the groundwater crisis, community-managed networks using low-cost tensiometers were deployed across 50,000 hectares. Combined with laser land levelling, this reduced water application by 20–30% in rice-wheat systems.
- **Andhra Pradesh's Micro-Irrigation Mission:** This state-wide program covers 2.5 million hectares, benefiting 1.8 million farmers. By linking IoT sensors to command centers, the state enables real-time monitoring and rapid problem resolution for smallholders.
- **North-western Plains (Punjab and Haryana):** These regions prioritize high-efficiency systems for water-intensive staples like rice and wheat to combat severe groundwater depletion. Drip irrigation in paddy through direct seeded rice (DSR) techniques has demonstrated water savings of up to 60%.
- **Southern Peninsula (Karnataka and Tamil Nadu):** These states leverage precision tools for high-value horticultural clusters. Karnataka leads in micro-irrigation for sugarcane and pomegranate, while Tamil Nadu integrates drip systems with mulching for banana and coconut plantations.
- **Arid West (Rajasthan and Gujarat):** Rajasthan utilizes drip irrigation for pearl millet and cluster beans to supplement rainfed farming. Gujarat has seen widespread success with micro-sprinklers for groundnut and cotton crops.
- **Karnataka's Ramthal Project:** Asia's largest integrated drip irrigation project, covering 24,000 hectares, proves that community-managed precision is possible.
- **Haryana's "Mera Pani Meri Virasat":** A successful policy-driven crop diversification from paddy to maize using micro-irrigation incentives.

Global market potential (2025–2030)

The global precision irrigation market is projected to grow from USD 9.56 billion in 2025 to USD 16.98 billion by 2032, at a CAGR of 8.47%

(Research and Markets, 2025). Drivers include the "net-zero" corporate pledges and rising food prices.

Indian Market Potential (2025–2030)

India is the fastest-growing market in the Asia-Pacific. The India Precision Irrigation Market is valued at USD 0.71 billion in 2025 and is expected to reach USD 1.19 billion by 2030 with 10.9% CAGR. (Research and Markets, 2025).

Government support & policy framework

- ✓ **PMKSY (Pradhan Mantri Krishi Sinchai Yojana) - (Per Drop More Crop):** The flagship scheme has covered 95.58 lakh hectares with a total release of ₹21,968 crore (2016–2025).
- ✓ **Ministry of Jal Shakti / National Water Mission:** Driving the "Jal Shakti Abhiyan-Catch the Rain" campaign and the Bureau of Water Use Efficiency (BWUE), which targets a 20% improvement in WUE.
- ✓ **Atal Bhujal Yojana:** A ₹6,000 crore scheme focusing on community-led groundwater management in 7 states.
- ✓ **Central Ground Water Board (CGWB):** Provides the NAQUIM (National Aquifer Mapping) data essential for precision planning.

Role of financial institutions

Banking giants like State Bank of India (SBI) and NABARD are bridging the credit gap. SBI's Agri-Term Loans offer competitive rates (7.5–9.75%) for installing micro-irrigation systems. NABARD's Micro Irrigation Fund (MIF), with a doubled corpus of ₹10,000 crore, allows states to provide additional top-up subsidies, making the technology affordable for the poorest farmers.

Recommendations and the way ahead for precision irrigation

A. The data & digital revolution

The transition from manual scheduling to predictive automation is the cornerstone of modern irrigation.

- **AI-Driven forecasting:** Using machine learning to process ETc (crop evapotranspiration) data alongside real-time soil moisture sensor feeds allows for precise "just-in-time" watering.
- **Digital twins:** Creating a virtual replica of a farm allows managers to run "what-if" scenarios to optimize water distribution without risking actual crop stress.
- **Blockchain accounting:** Provides an immutable ledger for water usage, which is essential for carbon credit verification and water-trading schemes.

B. Next-gen material science

Future-proofing irrigation involves looking at the molecular level to improve efficiency and reduce environmental impact.

- **Nanotechnology:** "Smart" delivery systems can utilize nano-encapsulated water droplets that release only when triggered by specific chemical signals from plant roots.
- **Biodegradable sensors:** To prevent "electronic trash" in fields, sensors made of organic materials can monitor soil health and then naturally decompose at the end of the season.

C. The circular economy: Waste-to-wealth

Sustainability is achieved by treating wastewater and agricultural by-products as valuable resources rather than liabilities.

- **Treated municipal waste water:** Utilizing IC-EcoWS (Innovation Centre for Eco-Prudent Wastewater Solutions), urban sewage is recycled into nutrient-rich water. This provides a reliable, climate-resilient supply that reduces ground water dependency and adds essential minerals to crops.
- **Agro-industrial waste:** Pro-cessed via Vermicomposting or enzyme technology, residues like rice husks become potent bio-fertilizers.

These amendments improve Soil Organic Carbon (SOC), enhancing moisture retention and maximizing the efficiency of every drop applied.

- **Livestock and animal waste:** Through anaerobic biogas digestion, manure produces clean energy and organic slurry. Methane powers irrigation pumps, while the nutrient-dense digestate is used for fertigation, delivering liquid gold directly to the roots.
- **Crop residues to biochar:** Using Pyrolysis, biomass is converted into biochar. This stable carbon acts as a permanent soil sponge, significantly increasing water-holding capacity and preventing nutrient leaching, making precision systems far more effective.

D. Socio-economic scaling models

High-tech tools are only effective if they are accessible to smallholder farmers. The "Way Ahead" focuses on democratizing technology.

- **Irrigation-as-a-Service (IaaS):** Startups provide mobile-controlled pumping and precision drip setups where farmers pay based on volume (kg/m3) rather than owning expensive hardware.
- **Community-Led Resource Management:** Empowering Farmer Producer Organizations (FPOs) and women-led Self-Help Groups (SHGs) to centralize the management of Water User Associations. This model ensures the equitable distribution of water resources and the efficient "Uber-ization" of precision farming equipment through localized leadership.

E. Integrated Farming Systems

Precision irrigation should not exist in a vacuum; it must be integrated into modern urban and peri-urban farming architectures.

- **Hydroponics & vertical farming:** Utilizing treated wastewater in controlled environments to maximize yield per drop.
- **Renewable synergy:** Coupling solar-powered pumps with precision sensors to ensure that the energy used for water delivery is as green as the water itself.

Conclusion

Precision irrigation marks India's decisive shift from flood-based excess to fine-tuned water stewardship. By combining drip, sprinkler, protected cultivation, and sensor-driven automation, farmers can routinely save 30–65% water while boosting yields and water productivity. Public policy (PMKSY, NWM, Atal Bhujal, CGWB's NAQUIM) now converges with digital tools, circular bioeconomy innovations, and climate-resilient water sourcing to mainstream these practices. Banks such as SBI, through YONO Krishi and targeted agri-term loans, along with NABARD's refinance and Micro Irrigation Fund, are turning high upfront costs into manageable investments. With finance, technology, and community institutions aligned, precision irrigation can secure India's hydrological future and sustain its role as a resilient food provider.

■■■

INNOVATION

ELECTROCULTURE IN VEGETABLE CROPS

MYTH OR SCIENCE ?

About Author

Darshan B. Kasundra
M.Sc. (Hort.) Vegetable Sci.
Hasmukh N. Leua
Associate Professor
Department of Fruit Science
College of Horticulture,
Sardarkrushinagar Dantiwada
Agricultural University, Jagudan,
Gujarat
Nirbhay M. Busa
Krishnkumar P. Donda
M.Sc. (Horticulture)
Floriculture & Landscaping
Department of Horticulture, B. A.
College of Agriculture, Anand
Agricultural University, Anand,
Gujarat

Electroculture is an unconventional agronomic approach that involves the application or manipulation of electrical energy to stimulate plant growth and improve crop performance. Although the concept has existed for more than two centuries, it has recently regained attention due to increasing interest in sustainable and low-input agricultural practices. In vegetable crops, electroculture is claimed to enhance seed germination, nutrient uptake, growth, yield, and tolerance to biotic and abiotic stresses. However, the scientific credibility of electroculture remains controversial.

Introduction

Vegetable crops are intensively cultivated and highly responsive to environmental and management interventions. Modern vegetable production systems face challenges such as declining soil health, high fertilizer dependency, pesticide resistance, and increasing climatic stresses. These challenges have stimulated interest in alternative and non-chemical technologies that may enhance crop performance while reducing external inputs.

Electroculture is one such technique that proposes the use of electrical energy either atmospheric or artificially generated to stimulate physiological processes in plants. Despite widespread claims by practitioners, electroculture remains scientifically disputed due to inconsistent experimental results and the absence of standardized methodologies.

History

Electroculture in vegetables has a long but uneven history. It began in Europe in the mid-18th century, when early scientists like Maimbray and Abbé Nollet experimented with electricity on plants. By the 19th century, Joseph Priestley documented these trials, and electroculture became a subject of curiosity across Britain, France, and later the US, Russia, and Japan. In the early 20th century, governments funded secret research, hoping electricity could boost crop yields, though results were inconsistent. Despite skepticism, some studies reported improved germination, growth, and disease resistance in vegetables such as tomatoes, cucumbers, and leafy greens. In India, electroculture research began in the mid-20th century, with trials on brinjal, tomato, and okra. Agricultural universities tested electric currents and magnetic fields, but adoption remained limited due to mixed outcomes compared to conventional agronomy. Today, electroculture is still experimental in India, but rising interest in organic and sustainable farming has revived attention to its potential as a low-input, eco-friendly method for vegetable production.

Scientific basis of electroculture

Electroculture is grounded in the fundamental understanding that plants are electrochemical systems. Electrical phenomena are intrinsic to plant life and regulate multiple physiological processes, including nutrient uptake, cell elongation, stress signaling, and growth regulation.

Electrical properties of plant cells

Plant cells maintain a transmembrane electrical potential, typically ranging from −120 to −160 mV, generated by proton pumps (H^+-ATPases) and selective ion channels. This membrane potential is essential for:

- Ion transport,
- Root hair development,
- Cell expansion,
- Signal transduction.

Electroculture hypothesizes that externally applied electric fields can modify these natural electrical gradients and enhance physiological efficiency.

Soil as an electrochemical medium

Soil functions not only as a physical support system but also as a dynamic electrochemical environment. Nutrient elements in soil exist predominantly in ionic forms and their mobility is influenced by electrical gradients.

Ion movement under electric fields

When an electric field is applied:

- Cations (K^+, Ca^{2+}, Mg^{2+}) migrate toward the cathode.
- Anions (NO_3^-, SO_4^{2-}) migrate toward the anode.

This principle forms the core theoretical justification for electroculture, suggesting enhanced nutrient availability and uptake by plant roots under controlled electrical stimulation.

Electroculture techniques used in vegetable crops

Atmospheric electroculture

This method employs metal antennas (commonly copper or iron) installed in the soil to capture atmospheric electricity. The collected charge is believed to be transferred to the rhizosphere, stimulating root activity and nutrient absorption.

Direct Current (DC) Application

Low-voltage direct current is applied to the soil or irrigation system for controlled durations. This approach requires precise regulation to avoid phytotoxic effects.

Pulsed Electric Field (PEF) treatment

Short electrical pulses are applied to seeds or seedlings. Among all electroculture methods, seed-level electrical treatment has shown the most consistent positive results.

Electrostatic field exposure

Plants are exposed to static electric fields without direct electrical contact. This non-invasive technique minimizes tissue damage but requires controlled experimental conditions.

Physiological effects of electroculture in vegetable crops:

Seed germination and early seedling growth

Electrical stimulation can increase seed coat permeability, enhance water imbibition, and activate hydrolytic enzymes. Studies have reported improved germination rates and uniform seedling emergence in tomato, cucumber, lettuce, and spinach.

Root growth and nutrient uptake

Electric fields influence root orientation (electro-tropism) and increase membrane permeability, potentially enhancing ion uptake efficiency. Improved root architecture under mild electrical stimulation has been reported in controlled experiments.

Photosynthesis and metabolic activity

Electrical stimulation may enhance chlorophyll synthesis, stabilize photosynthetic membranes, and improve electron transport efficiency. These effects can result in increased photosynthetic rates and biomass accumulation.

Hormonal regulation

Electrical signals interact with plant hormone pathways, particularly auxins, cytokinins, and abscisic acid. Modulation of hormonal balance may explain observed effects on growth and stress responses.

Role of electroculture in stress tolerance

Abiotic stress mitigation

Electroculture has been proposed to improve tolerance to drought, salinity, and temperature extremes by:

- Enhancing root hydraulic conductivity.
- Improving ion selectivity (K^+/Na^+ balance).
- Reducing oxidative stress.
- However, field-level evidence remains limited.

Biotic stress interaction

Electrical stimulation may strengthen cell walls through calcium signaling and induce defense-related enzymes. Nonetheless, consistent pest and disease suppression under electroculture has not been conclusively demonstrated.

Experimental evidence in vegetable crops

Experimental studies on electroculture show highly variable results:

- Positive responses under controlled laboratory and greenhouse conditions.
- Minimal or inconsistent effects in open field experiments.

The variability arises from differences in voltage intensity, exposure duration, soil type, crop species and growth stage.

Critical limitations of electroculture

- Absence of standardized protocols.
- Narrow threshold between stimulation and stress.
- Difficulty in scaling from laboratory to field conditions.
- Limited peer-reviewed research specific to vegetable crops.

These limitations prevent electroculture from being recommended as a mainstream agronomic practice.

Myth or Science?

Electroculture cannot be dismissed entirely as a myth, as plant responses to electrical stimuli are scientifically established. However, the lack of reproducible, large-scale field evidence prevents its classification as a validated agricultural technology. Electroculture currently occupies a transitional position between experimental science and alternative farming practice.

Future research directions

Future research should focus on:

- Molecular and genetic responses to electric fields.
- Crop-specific and stage-specific protocols.
- Long-term, multi-location field trials.
- Integration with nutrient and water management strategies.

Conclusion

Electroculture in vegetable crops represents a scientifically plausible concept rooted in plant electrophysiology and soil electrochemistry. However, its agronomic application remains insufficiently validated. Until robust, standardized, and reproducible evidence becomes available, electroculture should be considered an experimental and supplementary approach rather than a replacement for established crop management practices.

■■■

SOIL HEALTH

THE MICROBE-AI SYNERGY

INDIA'S SOIL HEALTH REVOLUTION IN 2026

About Author

Abhilashaa Das
Senior Research Fellow,
Department of Agricultural Meteorology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia

It is 5:30 AM in a small village in India. Rajesh, a second-generation farmer, begins his day not by scanning the horizon for rain clouds, but by opening an app on his smartphone. A colour-coded dashboard of his 5-acre field appears on the screen: a soil health interface powered by satellite inputs, local weather data, and AI-based analytics.

A voice alert in his native language informs him: "High surface temperature recorded yesterday. Soil microbial activity may decline in the north plot. Recommended: apply bio-fertilizer mix before 10:00 AM to improve nutrient availability."

A decade ago, this would have sounded improbable. In 2026, it represents a powerful transformation unfolding across Indian agriculture, the integration of microbial science with artificial intelligence. India is entering what many experts are calling the *Living Soil Revolution*, a shift from chemical dependency toward biological intelligence, guided by data-driven decision-making.

The invisible workforce beneath our feet

The Green Revolution boosted yields through synthetic fertilizers, especially NPK (Nitrogen, Phosphorus, and Potassium). While this strategy delivered short-term productivity gains, long-term overuse often weakened soil structure, reduced organic carbon, and disrupted beneficial microbial ecosystems. In 2026, the focus is returning to the soil's natural workforce, microbes.

Nitrogen fixers: The living fertilizer

Atmospheric nitrogen cannot be directly absorbed by plants. Beneficial bacteria such as *Azotobacter* and *Rhizobium* convert it into plant-available

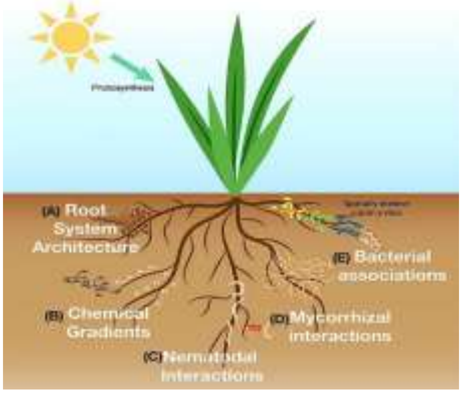


Image 1: Schematic illustration of plant root system architecture showing interactions with soil microbes, including mycorrhizal fungi and beneficial bacteria that enhance nutrient uptake and soil health

forms. These microbes provide a steady nitrogen supply, reducing excessive dependence on synthetic urea.

Bio-fertilizers are no longer viewed as optional supplements. They are increasingly becoming integral to nutrient management systems across several states.

Phosphorus solubilizers: Unlocking bound nutrients

A significant proportion of phosphorus applied over the years remains chemically fixed in soils. Phosphate-solubilizing bacteria release organic acids that free this locked nutrient, improving nutrient use efficiency while minimizing runoff losses. This enhances both productivity and environmental sustainability.

Mycorrhizal fungi: The underground network

Arbuscular Mycorrhizal Fungi (AMF) create symbiotic networks with plant roots, effectively increasing the root's absorption surface. This improves water uptake, strengthens soil aggregation, and enhances drought tolerance. In climate-stressed regions, these fungal partnerships are becoming critical for maintaining crop resilience.

Artificial intelligence: The microbial manager

One of the long-standing challenges with biological inputs was variability. Their performance depended heavily on soil temperature, moisture, crop stage, and agro-climatic conditions. Artificial Intelligence is changing that equation.

Hyperlocal soil diagnostics

Modern advisory systems integrate:

- Satellite-derived vegetation indices.
- Automatic weather station data.
- Soil moisture readings.
- Historical yield patterns.

AI platforms process these datasets to recommend precise application timing for biological inputs.

Image 3: Portable soil diagnostic tools enable real-time assessment of field conditions, supporting AI-driven decisions that enhance microbial activity and nutrient efficiency.

From reactive to predictive farming

Traditional farming often responded to visible stress. The

Image 4: Automated field sensor supporting real-time monitoring in precision agriculture systems.

2026 model emphasizes prediction. AI algorithms analyze heat stress forecasts, rainfall variability, and crop growth stages to generate preventive advisory. Instead of reacting to nutrient deficiency symptoms, farmers now receive early-stage alerts. This marks a shift from intuition-based farming to insight-driven management.

Soil health and the emerging carbon economy

Improved microbial activity contributes to increased soil organic carbon. Regenerative practices such as residue incorporation, reduced tillage, and biochar application enhance both soil structure and microbial habitats.

As India strengthens its carbon market architecture, measurable soil carbon improvements are gaining policy

Image 2: Biochar application in agricultural fields to enhance soil health and carbon storage

attention. While systems are evolving, discussions around carbon-linked incentives for sustainable practices are expanding rapidly. The transition toward living soils is not just ecological, it is economic.

Digital literacy: The catalyst for adoption

The success of biological and AI integration depends on accessibility. With rising rural broadband penetration, farmers increasingly access:

- Real-time soil advisory.
- Crop-stage recommendations.
- Weather-based alerts.
- Market intelligence.

Voice-enabled platforms in regional languages are accelerating smallholder adoption. Women-led initiatives in precision agriculture and digital advisory services are further strengthening grassroots participation.

Strategic Planning for Kharif 2026

As Kharif approaches, agronomists emphasize crop-specific microbial strategies:

- Match strains to soil type and climate.
- Integrate biological inputs with reduced chemical doses.
- Enhance soil organic carbon before monsoon.
- Monitor field response through digital tools.

The focus is no longer on input quantity- but on input intelligence.

The road ahead

The vision of Viksit Bharat 2047 demands climate resilience, reduced dependency on imports, and sustainable intensification. The alliance between microbes and Artificial Intelligence directly contributes to this vision by combining:

- Biological restoration.
- Digital precision.
- Regenerative agriculture.
- Farmer-centric advisory systems.

The 2026 strategy for every progressive farmer is clear:

- Analyze before applying.
- Restore before intensifying.
- Integrate biology with technology.
- Let data guide decisions.

Conclusion

The future of Indian agriculture will not be secured by chemicals alone, nor by technology alone. It will be shaped by their thoughtful integration. Satellites may provide the eyes. AI may provide the brain. But microbes remain the foundation. When we restore living soils, we restore resilience, productivity, and rural prosperity. The Living Soil Revolution has begun!

Previous Issues

Website Statistics (Jan. 2026)

142K
Monthly Pageview

25K
Monthly Visitor

3.7M
Monthly Impression

Social Stats

6.5K

6.1K

10.0K

1.7K

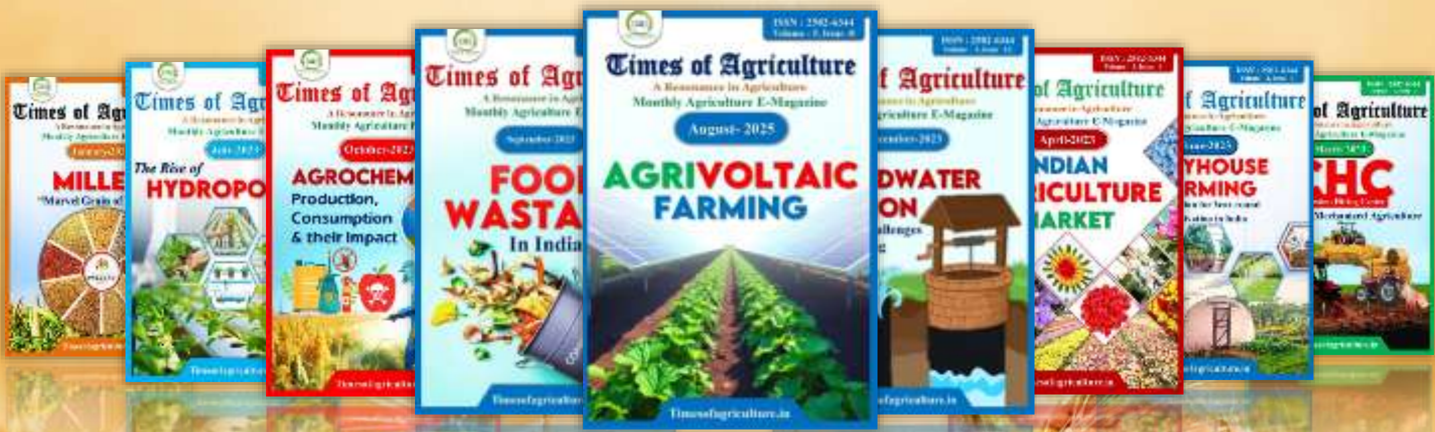
2.1K

Times of Agriculture

A Resonance in Agriculture

Monthly Agriculture e-Magazine

ISSN No. : 2582-6344



SCAN ME

Timesofagriculture.in