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INNOVATIVE CROP NUTRITION

Unlocking Productivity, Profitability and Resilience in Indian Agriculture



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MESSAGE

India's agriculture sector has been a cornerstone of the nation's economic growth, food security, and rural livelihoods. Today, as the country strives to meet the food and nutritional needs of a growing population while addressing the challenges of climate change, resource degradation, and evolving consumer preferences, the imperative for enhancing agricultural productivity sustainably has never been greater.

India has emerged as one of the world's leading agricultural producers, yet productivity across several major crops continues to lag global benchmarks. With limited scope for expanding cultivable land and increasing pressure on natural resources, future growth in agricultural output will depend significantly on improving productivity, resource-use efficiency, and the resilience of farming systems. At the same time, challenges such as imbalanced fertilizer use, declining nutrient- use efficiency, widespread micronutrient deficiencies, soil degradation, and a rising fertilizer subsidy burden underscore the need for a more scientific and sustainable approach to crop nutrition.

It is in this context that FICCI presents this report, **Innovative Crop Nutrition: Unlocking Productivity, Profitability & Resilience in Indian Agriculture**. The report examines the transformative potential of innovative crop nutrition solutions- including micronutrients, liquid fertilizers, biostimulants, water-soluble fertilizers, and advanced nutrient technologies- in addressing India's productivity and sustainability challenges. These solutions offer significant opportunities to enhance nutrient use efficiency, improve crop yields and quality, strengthen resilience to climatic stresses, and support balanced nutrient management practices.

The report also highlights the evolving policy and regulatory landscape, identifies key barriers to adoption, and outlines actionable recommendations for industry and government to accelerate the deployment of innovative crop nutrition solutions at scale.

As India advances towards its vision of a resilient, productive, and sustainable agricultural sector, fostering innovation in crop nutrition will be critical to unlocking the next phase of agricultural transformation. We hope this report serves as a valuable resource for policymakers, industry leaders, researchers, and other stakeholders working collectively to strengthen India's agricultural future.

Anant Swarup
Secretary General
FICCI



MESSAGE

To help India achieve a $10 trillion GDP by 2035, the agricultural sector must double its Gross Merchandise Value (GMV) to $1.20 trillion. The path to economic growth clearly runs through India's farmlands. However, agriculture stands at a crossroads, requiring a balance between driving productivity and ensuring sustainability amid escalating climate risks.

Innovation in crop nutrition will be the transformative force shaping this future. As a member of the FICCI Task Force on Innovative Crop Nutrition, I am honoured to collaborate with industry leaders, policymakers, researchers, and farmers to accelerate change on the ground.

Our ultimate success depends on integrating science, technology, and sustainable agronomics directly into farm-level decisions. Innovative crop nutrition spanning micronutrients, liquid fertilisers, water soluble fertilisers, biostimulants, nano fertilisers etc can significantly improve nutrient use efficiency, enhance crop productivity, and help restore soil health. Crucially, this shift offers a powerful mechanism to reduce the national subsidy burden while delivering superior economic returns for farmers and protecting the environment.

This report establishes a shared understanding of the opportunities and challenges in this space. It highlights the urgent need for an enabling ecosystem that fosters innovation, supports adoption, and ensures technology remains accessible to everyday farmers. Through coordinated action and sustained commitment, we can unlock the full potential of innovative crop nutrition—driving agricultural growth, strengthening food security, and advancing India's vision of a resilient, sustainable farming sector.

Sanjiv Kanwar
Chairman, FICCI Task Force on Innovative Crop Nutrition and
Managing Director, Yara South Asia & Country Head, Yara India



FOREWORD

Crop nutrition is emerging as one of the most critical pillars of India's agricultural transformation. As the country seeks to enhance farm productivity, improve farmer incomes, strengthen food security and build resilience against climate variability, the role of efficient and sustainable nutrient management has never been more important.

The challenges confronting crop nutrition today are fundamentally different from those of the past. While India has made remarkable progress in ensuring food self-sufficiency, productivity across several crops continues to remain below global benchmarks. In cereals, India's average productivity stands at ~3.6 MT/Ha, compared to the global average of 4.2 MT/Ha. Similar yield gaps persist across pulses, oilseeds, fiber crops and vegetables. Crop nutrition is expected to play a critical role in boosting crop productivity. However, declining nutrient use efficiency, widespread soil degradation, growing micronutrient deficiencies and increasing environmental concerns are placing unprecedented pressure on existing crop nutrition practices. This demands a new approach to crop nutrition that is science-led, precision-based and sustainability-oriented.

India is poised for this transition. Innovative crop nutrition solutions, including specialty fertilisers, bio-based nutrition and advanced precision nutrient products are emerging as alternatives that could drive the next cycle of growth in agricultural productivity. These solutions have the potential to improve nutrient use efficiency, enhance crop productivity, reduce environmental footprints and deliver better economic outcomes for farmers. Beyond farm-level benefits, they can contribute to reducing import dependence, optimising fertiliser subsidy expenditure and strengthening the competitiveness of Indian agriculture.

Unlocking this opportunity will require accelerated investment in research and development, an innovation-friendly regulatory environment, stronger industry-academia collaboration and robust last-mile extension systems.

The Government of India, along with various state governments, has demonstrated clear intent in building an innovative crop nutrition ecosystem. Initiatives such as soil health cards, PM PRANAM Yojana, Paramparagat Krishi Vikas Yojana and GST rationalisation are a few of them. These efforts have laid a strong foundation for the sector's transformation. The next phase of growth will however require a sharper policy focus on accelerating the development, commercialisation and adoption of innovative crop nutrition solutions.

YES BANK is pleased to be the Knowledge Partner with FICCI for the inaugural edition of the 'India Innovative Crop Nutrition Conclave 2026', during which this report titled 'Innovative Crop Nutrition: Unlocking Productivity, Profitability and Resilience in Indian Agriculture' is being released. This report describes the landscape of innovative crop nutrition solutions, enumerates critical challenges faced by this sector's ecosystem and identifies pathways for unlocking India's agricultural potential using innovative crop nutrition. As a Bank deeply committed to supporting India's agricultural transformation, we believe that this report will serve as a valuable reference for all stakeholders committed to strengthening India's agriculture ecosystem.

Sincerely,

Manish Jain
Executive Director
YES BANK Ltd.


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Executive Summary



India's agriculture sector has undergone a remarkable transformation over the past six decades, evolving into one of the world's largest and most diverse production systems. This progress has enabled the country to meet the food and nutritional needs of a rapidly growing population while supporting broader economic development. Between 1960-61 and 2024-25, India's total crop output increased from 231 Mn MT to 1,228 Mn MT, an increase of over 431%. Within this, foodgrain production increased by over 336%, while fruits and vegetables increased by 950%.[1] This achievement has been driven by increased acreage under irrigation, the widespread adoption of high yielding varieties, increased fertiliser use, strengthened farmer level extension services and sustained technological advancements across the agricultural value chain.

Despite these achievements, India continues to face a significant productivity gap vis-à-vis global benchmarks across several major crops. In cereals, India's average productivity stands at 3.6 MT/Ha, while China (the largest producer) is at 6.5 MT/Ha and the USA (second largest producer) at 8.4 MT/Ha. India's cereals productivity also remains lower than the global average of 4.2 MT/Ha. Similar yield gaps persist across pulses, oilseeds, fiber crops and vegetables, where productivity trails the world average by 18%, 43%, 39% and 19% respectively.[2] These gaps are driven by structural constraints including fragmented landholdings, inadequate irrigation coverage, increasing water stress, imbalanced nutrient application, limited adoption of modern agronomic practices and declining soil health. As a result, productivity gains have moderated, constraining the sector's ability to fully capitalize on growing domestic and export opportunities.

Bridging this productivity deficit is becoming increasingly critical as demand for agricultural produce continues to rise. Demand projections indicate that India's foodgrain production needs to increase from current levels of 358 Mn MT (2024-25) to 400 Mn MT by 2050, while fruit and vegetable production needs to grow from 334 Mn MT (2024-25) to over 650 Mn MT by 2050.[3] Meeting this demand sustainably will require a renewed focus on productivity enhancement, driven by greater resource efficiency, improved farm practices and technology led interventions. **In this transition, crop nutrition will play a pivotal role in enabling higher yields, improving input-use efficiency and strengthening the resilience of agriculture production systems.**

[1] Agriculture Statistics at a Glance 2024–25, MoA&FW. Total crop output excludes cotton and jute.
[2] FAOSTAT 2024
[3] ICAR-Vision 2050, Agriculture Statistics at a Glance 2024-25, MoA&FW

Against this background, this report outlines the role of innovative crop nutrition, defines its broad landscape, outlines the key challenges that this sector faces and highlights the pathways for unlocking India's agricultural potential through innovative crop nutrition.

Chapter one of the report highlights the pressing need for transitioning towards innovative crop nutrition. Nutrient use in India remains highly imbalanced, with fertiliser consumption being driven largely by nitrogen intensive application. Over the last five decades, while fertiliser use has increased significantly, the corresponding productivity response has progressively weakened. Further, reduced use of organic manures and injudicious use of inorganic fertilisers have caused a decline in soil organic matter and degraded soil health.

The challenge is further compounded by a subsidy regime that continues to favour nitrogen-intensive nutrient application. For 2026-27, the fertiliser subsidy has been budgeted at INR 1.71 lakh crore, equivalent to 3.2% of the Union Government's budget. This is higher than the 2.6% of budget allocation for agriculture. Of this subsidy allocation, about 68% (INR 1.17 lakh crore) has been earmarked for urea, with balance supporting nutrient-based subsidies. This structure not only encourages imbalanced nutrient use but also imposes a significant and growing fiscal burden, underscoring the need to promote a more balanced and efficient nutrient management framework.

Transitioning towards innovative and efficiency driven fertiliser consumption presents a significant opportunity to improve both agricultural productivity and fiscal sustainability. A modest 8-10% improvement in nutrient use efficiency, achieved through innovative crop nutrition, could potentially generate ~INR 9,000-10,000 crores in subsidy savings, annually.[4] These savings could be strategically redirected to fund productivity enhancing and sustainable agricultural practices. Every percentage increase in crop productivity has the potential to translate into an incremental ~ INR 33,000 crores addition to the agricultural GVO.[5]

Chapter two of the report highlights the urgent need of transitioning towards innovative crop nutrition amidst the ongoing global crisis. India continues to rely on imports for several critical fertiliser products and raw materials. Approximately 20% of its urea requirement, and nearly 50% of di-ammonium phosphate (DAP) consumption is sourced from the Gulf region. Beyond finished fertilisers, domestic fertiliser manufacturing remains heavily reliant on imported feedstocks and energy inputs. Natural gas accounts for up to 70% of urea production costs and nearly 85% of the natural gas consumed by India's urea industry is imported[6]. As a result, India's fertiliser sector is not merely import-dependent; it is strategically linked to global energy and logistics networks. Consequently, geopolitical disruptions rapidly translate into higher input costs, supply uncertainties, increased subsidy requirements, and inflationary pressures across the agricultural economy.

Chapter three of the report presents the landscape of innovative crop nutrition and highlights its potential to transform agricultural productivity. At its core, innovative crop nutrition focuses on delivering the right nutrient, in the right form, at the right time and through the right application pathway to maximise nutrient uptake and utilisation by crops. By enhancing nutrient use efficiency, these solutions enable higher productivity from existing land and resource bases while reducing environmental impact. These solutions improve crop yields and quality, strengthen crop resilience against abiotic stresses, reduce environmental footprint, improve soil health, and in the process, contribute to higher farm incomes and sustainable agriculture development.

The innovative crop nutrition ecosystem comprises a diverse portfolio of advanced nutrient solutions designed to improve nutrient use efficiency and crop performance. This report examines key segments including liquid fertilisers, biostimulants, micronutrients, water-soluble fertilisers and other advanced macronutrient solutions, highlighting their role in driving productivity, profitability and resilience in agriculture.

[4] YES BANK Analysis
[5] 2023-24 crop GVO at current prices, YES BANK Analysis
[6] ICRIER-De-risking Fertiliser Supplies for India amid Rising Geopolitical Risks

Chapter four examines key government regulations and initiatives supporting the adoption of innovative crop nutrition solutions. The Government of India is increasingly shifting its focus from volume-centric fertiliser support towards interventions that promote precision, efficiency and innovation in crop nutrition. Through a combination of initiatives including expansion of micro irrigation system that forms the backbone of many innovative crop nutrition solutions, scaling up soil health diagnostics and introducing tax and policy reforms, the Government is actively supporting adoption of innovative nutrient solutions.

However, despite the trust and their demonstrated agronomic, economic and environmental benefits, the widespread adoption of innovative crop nutrition solutions in India remains limited. Multiple demand side and supply side barriers continue to constrain farmer uptake. The key challenges enumerated in chapter five include:

Farm level

- Limited awareness at ground level-Innovative crop nutrition solutions are often perceived as optional or supplementary rather than integral to crop management by the farmers.
- Upfront Cost Sensitivity and subsidy related price differences deter large scale adoption of innovative solutions.
- Risk aversion & preference for familiar inputs-With over 86%[7] of Indian farmers classified as small and marginal, risk aversion remains high, and input choices are biased towards familiar products that promise short-term certainty.
- Shortage of skilled farm labour, coupled with limited access to mechanisation and application equipment, act as an additional barrier to adoption at scale.
- Knowledge advisory & extension gaps-Public extension systems are largely oriented towards conventional fertiliser recommendations, with limited capacity to mainstream newer categories into standard agronomic advisories.

Infrastructure

- Testing and validation bottlenecks-RFCLs face significant volume pressure, especially during peak import seasons ahead of kharif and rabi sowing. While the number of notified laboratories has increased, testing capabilities, human resources and their skills have not expanded at the same pace as import volumes. This results in backlogs, extended turnaround times and delays in consignment clearance.
- Adoption barriers linked to farm infrastructure-Adoption of some advanced nutrients like liquid fertilisers, water soluble fertilisers etc. is closely linked with micro-irrigation and protected cultivation, which are still limited to a fraction of India's agricultural land. In the absence of this enabling infrastructure, the performance advantages are not fully realised and adoption remains limited.
- Distribution and storage limitations-Some innovative crop nutrition products are sensitive to heat and humidity. The absence of cold chain infrastructure in rural areas results in degradation in product quality during storage and transportation, leading to reduced efficacy and inconsistency at the farm level.

Supply chain

- Dependence on imported raw material-This exposes the supply chain to currency fluctuations, trade restrictions, and shifts in global political and economic conditions, making pricing volatile and planning uncertain for both manufacturers and distributors.

[7] Press Information Bureau, MoA&FW

- Innovation challenges-Developing new formulations requires substantial R&D expenditure. With long payback periods, inconsistent regulatory regime (with adhoc bans), weak IP protection and uncertain adoption at the farm level, industry faces challenges in justifying sustained investments, which limits the pace of innovation.
- Counterfeit products-Proliferation of counterfeit products not only erodes farmer trust and market integrity but also leads to reactive policy interventions that affect the entire crop nutrition industry.

Policy and Regulatory

- Complex registration and approval process-The processes for approval, notification, and inclusion of new products are rigorous, time-intensive, administratively complex and lack transparency in communication. A new fertiliser product registration in India takes around 800 days as compared to 90 days in USA, 30 days in the European Union and 15 days in Vietnam.[8]
- Decentralized approval under the FCO-Characterized by overlapping central and state-level processes, decentralized approval system often results in prolonged timelines. Industry feedback suggests that approval cycles can extend from 12-18 months before a product is eligible for commercialization.
- Policy volatility-especially at state level poses a major challenge for the non-subsidized fertiliser segment. Regulatory actions such as sudden license suspensions and product sales restrictions create an uneven and unpredictable operating environment.
- Weak Intellectual Property (IP) protection-Proprietary formulations, once registered, are relatively easy to replicate due to limited enforcement of protection norms and challenges in proving formulation-level infringement.
- Unclear provisions for registration of products for export-In the absence of defined pathways for export approvals, Indian manufacturers face constraints in accessing international markets, even where products meet global quality and performance standards.
- Inverted duty structure-Several key raw materials and intermediates used in micronutrient manufacturing continue to attract a higher GST rate of 18%, than the final product which is taxed at 5%.

Unlocking the full potential of innovative crop nutrition requires a coordinated, ecosystem-wide approach. Government action is critical to establishing a predictable, science-based regulatory framework, strengthening public testing and extension infrastructure and de-risking product innovation and early adoption. The private sector needs to continue driving research, product innovation, field validation and farmer engagement. Together, public–private collaboration can integrate data, technology and on-ground execution to accelerate large-scale adoption of innovative crop nutrition solutions. Chapter six of the report outlines a set of actionable recommendations for industry and the government. Together, these measures aim to accelerate adoption, reduce fiscal and environmental costs and position innovative crop nutrition as a cornerstone of India's next phase of agricultural transformation. Key recommendations include:

Actionable for Industry

- Developing farmer-centric sustainable products and business models-Industry must focus on innovating products and nutrition systems that are outcome-oriented and deliver consistent productivity gains, income improvement, and long-term soil health. Also, innovation in business models alongside products is important. Trial-based offerings and smaller pack sizes can lower entry barriers and encourage

[8] Enabling the Business of Agriculture, World Bank Group

experimentation. Partnerships with financial institutions, insurers, and agri-fintech players can enable credit-linked or outcome-based financing models that reduce upfront risk for farmers.

- Fostering farmer education and enabling evidence generation and validation-Industry efforts must move beyond awareness campaigns to structured, multi-season capability-building programmes. Moreover, collaboration of Industry with collective institutions such as FPOs and cooperatives can play a pivotal role in accelerating adoption by enabling peer learning, shared risk and collective action.
- Strengthening market access, distribution, and last-mile delivery-Ensuring timely product availability during critical crop stages is critical. Also, strengthening distribution by upgrading dealers and distributors from transactional intermediaries to trusted agronomic advisors is important.
- Adopting data driven and tech enabled solutions-Integrated demonstration ecosystems, developed in partnership with agritech firms, research institutions and state agencies can serve as centers that showcase the tangible benefits of precision nutrition while simultaneously building farmer capacity. The industry should also leverage the existing national datasets (on soil health, crop production etc.) to map nutrient deficiencies and soil characteristics against available crop nutrition products. This data-driven approach can enable companies to identify gaps, develop targeted solutions, optimize product portfolios, strengthen market outreach and improve the effectiveness of nutrient interventions at the farm level.

Actionable for Government

- Facilitating farmer outreach and adoption
  - Prioritising capacity building of extension officers to ensure they are equipped with up-to-date knowledge on advanced nutrients, precision application, and soil health management remains very critical.
  - Conducting awareness campaigns to help farmers understand the long-term benefits of adoption of balanced nutrition with innovative crop nutrients, including higher yields, lower input costs, and improved soil sustainability is important.
  - Evaluating the revision of Recommended Dose of Fertilisers (RDFs) based on evidence from trials.
- Re-orienting subsidy and incentive structures towards efficiency and balanced nutrition
  - Provision of grants (through capex grants, PLI type schemes), tax incentives, or dedicated funds for R&D focused on improving nutrient use efficiency can fast track innovation and commercialization in the innovative nutrient space.
  - Incentives for innovation in technology towards bringing in efficiencies in the supply chain may be considered.
  - Free market pricing of fortified fertilisers may be considered. Such an approach would enable manufacturers to recover the additional cost of fortification and improve product availability. On the other hand, farmers will be able to access a wider range of fortified products and can make informed choices based on crop requirements and expected productivity gains.
- Strengthening the testing infrastructure
  - Accreditation of a wider network of private and public laboratories under NABL for fertiliser and specialty nutrient testing can significantly reduce turnaround time and regional bottlenecks.

- Within the existing testing ecosystem, capacities need to be developed through infrastructure upgradation as well as skill building for new analytical methods.
- Importers need to be given the flexibility to undertake testing either through RFCLs or NABL accredited laboratories.

- Improving data collection and standardization
  - Enhancing the depth, frequency, and usability of soil health data can enable more precise nutrient recommendations and better targeting of interventions.
  - Creation of a standardized framework for soil testing methods across the country can ensure consistency and reliability of soil diagnostics.
  - Open-access, anonymised data platforms can support industry innovation, academic research, and evidence-based policymaking, while safeguarding farmer interests.
  - Creation of a central database for biostimulants will enhance transparency amongst stakeholders and align India's practices with global practices

- Creating an enabling policy and regulatory environment
  - Simplified inclusion of innovative speciality nutrients under FCO – through label claims or notification of general specifications for solid, liquid and micronutrient fertilisers (as has been done for WSFs).
  - Introduction of One Nation One License system
  - Setting up a single window system and enabling digital integration
  - Incorporation of comprehensive sustainability assessment framework-By incorporating sustainability parameters into the regulatory approval process, policymakers can incentivize the development and adoption of technologies that generate positive environmental impact while maintaining agricultural productivity.
  - Introducing a provision under the Fertiliser Control Order (FCO), analogous to Clause 9(3) of the Central Insecticide Board (CIB)- for exports
  - Harmonizing the classification of fertilisers and micronutrients under the Customs Tariff Act to remove ambiguity and ensure regulatory consistency.
  - Establishing a simplified, predictable, science-led and harmonised regulatory framework for biostimulants
  - Development of framework for nano fertilisers

- Strengthening stakeholder coordination
  - A structured coordination mechanism between the Departments/Ministries is essential to align nutrient policy with crop-specific agronomic requirements, evolving farming systems and national productivity objectives.
  - Institutionalized stakeholder consultations (both at central and state levels) involving industry, regulators, academia, and farmer bodies can support the development of calibrated policy responses that address the challenges without adversely impacting compliant and innovation-led businesses.

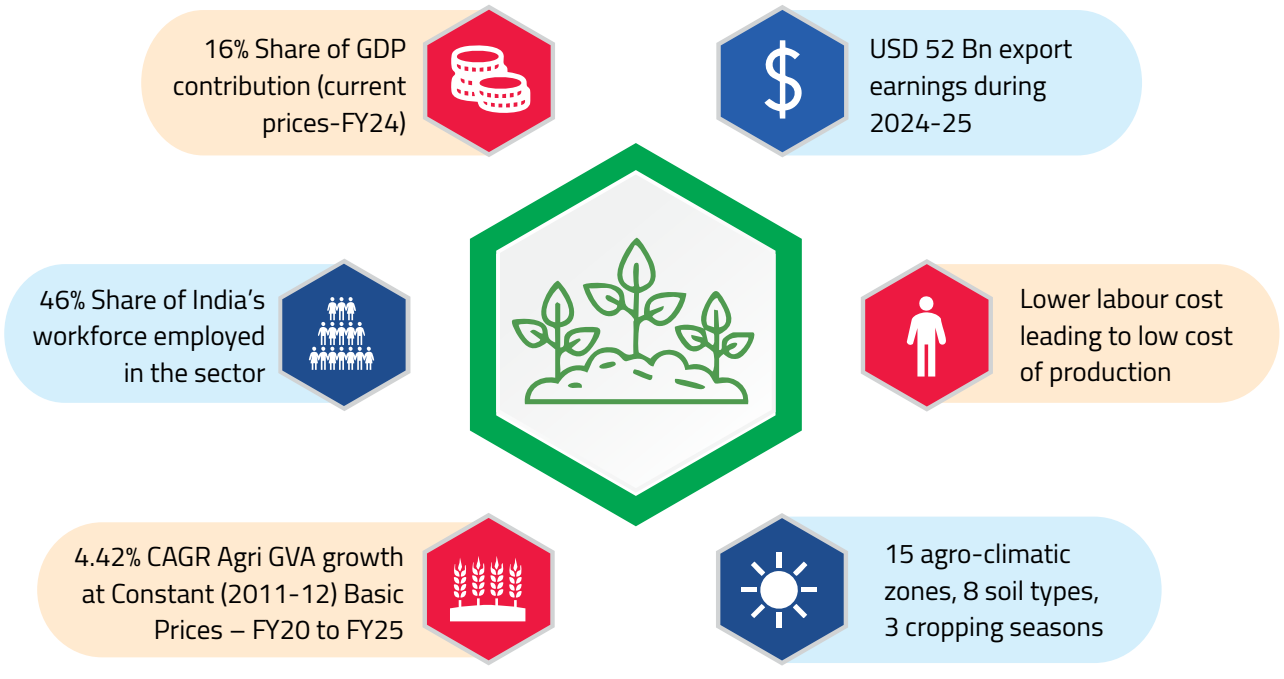
The future of Indian agriculture will be shaped by its ability to produce more with less land, less water and fewer natural resources. Innovative crop nutrition provides a critical pathway to achieve this objective by improving nutrient use efficiency, enhancing productivity and building resilience at the farm level. As the sector navigates evolving economic, environmental and food security challenges, accelerating the adoption of innovative crop nutrition solutions will be essential to unlock a more productive, profitable and sustainable agricultural future for India.

1 The Need for Innovative Crop Nutrition



Agriculture continues to serve as a strategic pillar of India's economy, livelihoods and food systems. The sector contributes about 16% to India's GDP, employs 46% of the workforce,[9] and contributes over USD 52 billion to India's export earnings[10] (refer exhibit 1).

Exhibit 1: Strategic importance and contribution of India's agriculture sector



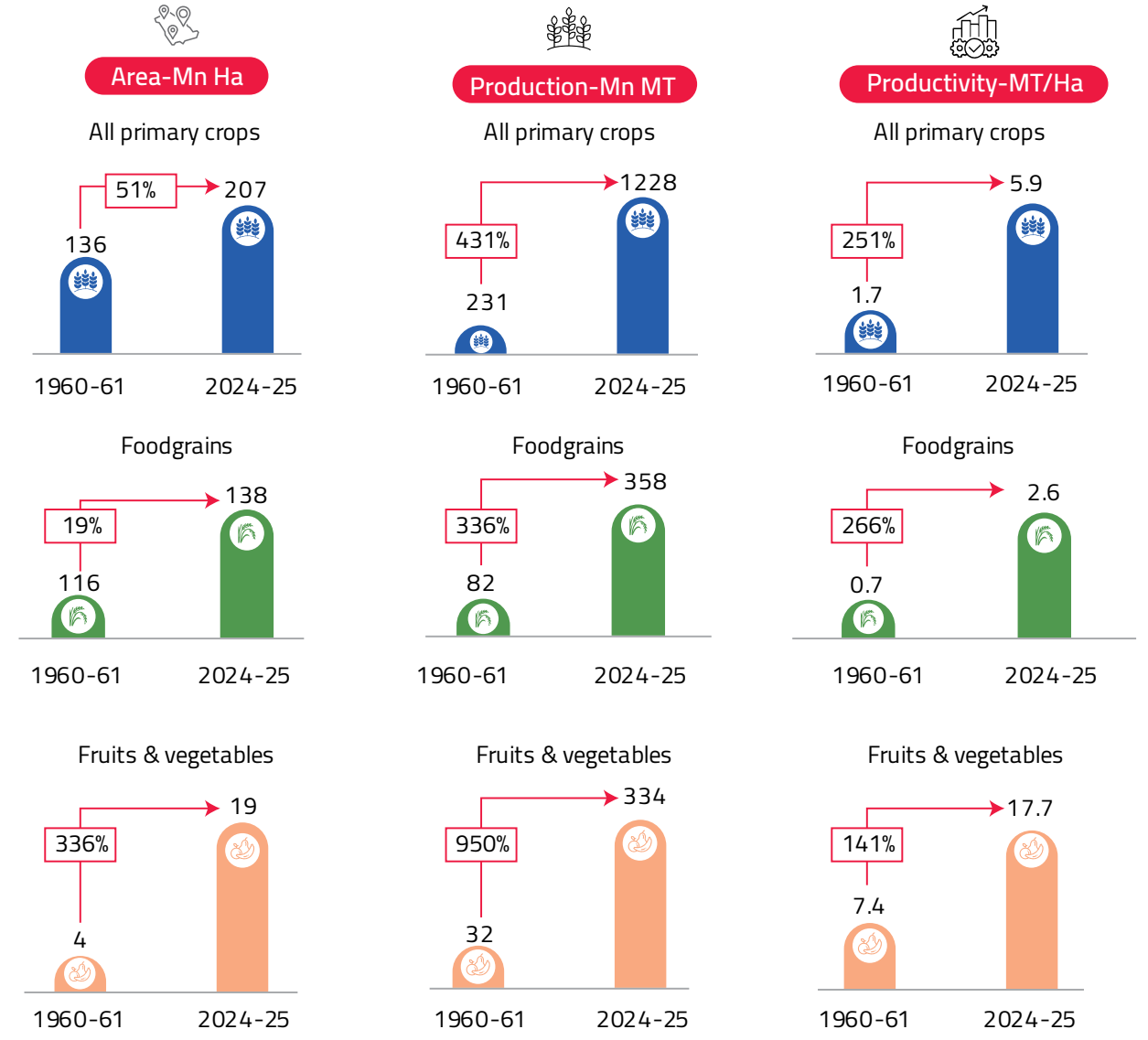
Source: Ministry of Agriculture and Farmers' Welfare, DGFT, Ministry of Statistics and Program Implementation, Economic Survey 2025-26, UPAg Portal, PIB, APEDA 2024-25

[9] Economic Survey of India 2024-25

[10] APEDA, PIB

India's agriculture sector has delivered a remarkable transformation over the past six decades. The country has built one of the world's largest and most diverse production systems, that has enabled the sector to meet the food and nutritional needs of a rapidly expanding population while supporting broader economic growth. Between 1960-61 and 2024-25, total crop output increased from 231 Mn MT to 1,228 Mn MT, an increase of over 431%. Within this, foodgrain production increased by over 336%, while fruits and vegetables increased by 950% (refer exhibit 2).[11]

Exhibit 2: Growth trend in area, production and productivity for overall agricultural crops, foodgrains and fruits & vegetables



Source: Agriculture Statistics at a Glance 2024–25, MoA&FW.

Total crop output excludes cotton and jute

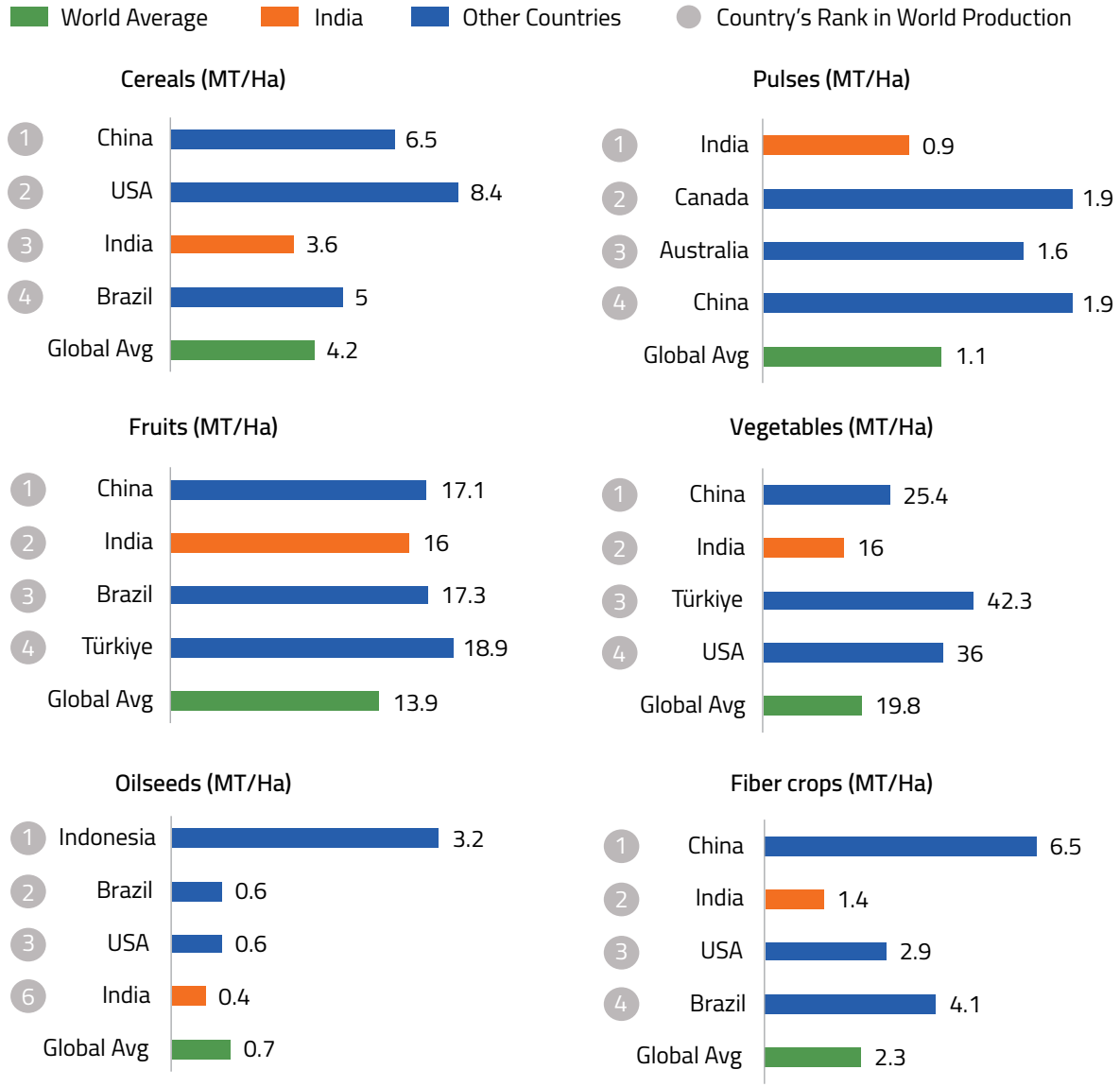
[11] Agriculture Statistics at a Glance 2024–25, MoA&FW. Total crop output excludes cotton and jute.

This growth story reflects the combined impact of increased acreage and improved productivity on account of multiple factors, including increased area under irrigation, higher adoption of high yielding varieties, increased fertiliser use and strengthened farm level extension among others.

The crop productivity imperative

While India has made notable progress in enhancing agricultural productivity, the gap vis-à-vis global benchmarks signals substantial headroom for productivity-led growth in output. For instance, in case of cereals, India's average productivity stands at 3.6 MT/Ha, which is lower than the global average of 4.2 MT/Ha. Similarly, India's yield stands below the global average across pulses, oilseeds, fiber crops and vegetables (where India's yield lags the world average by 18%, 43%, 39% and 19% respectively).[12] Exhibit 3 captures a comparison of productivity across key categories for India, other key producers and the global average.

Exhibit 3: Comparison of India's agricultural productivity vs. global benchmarks



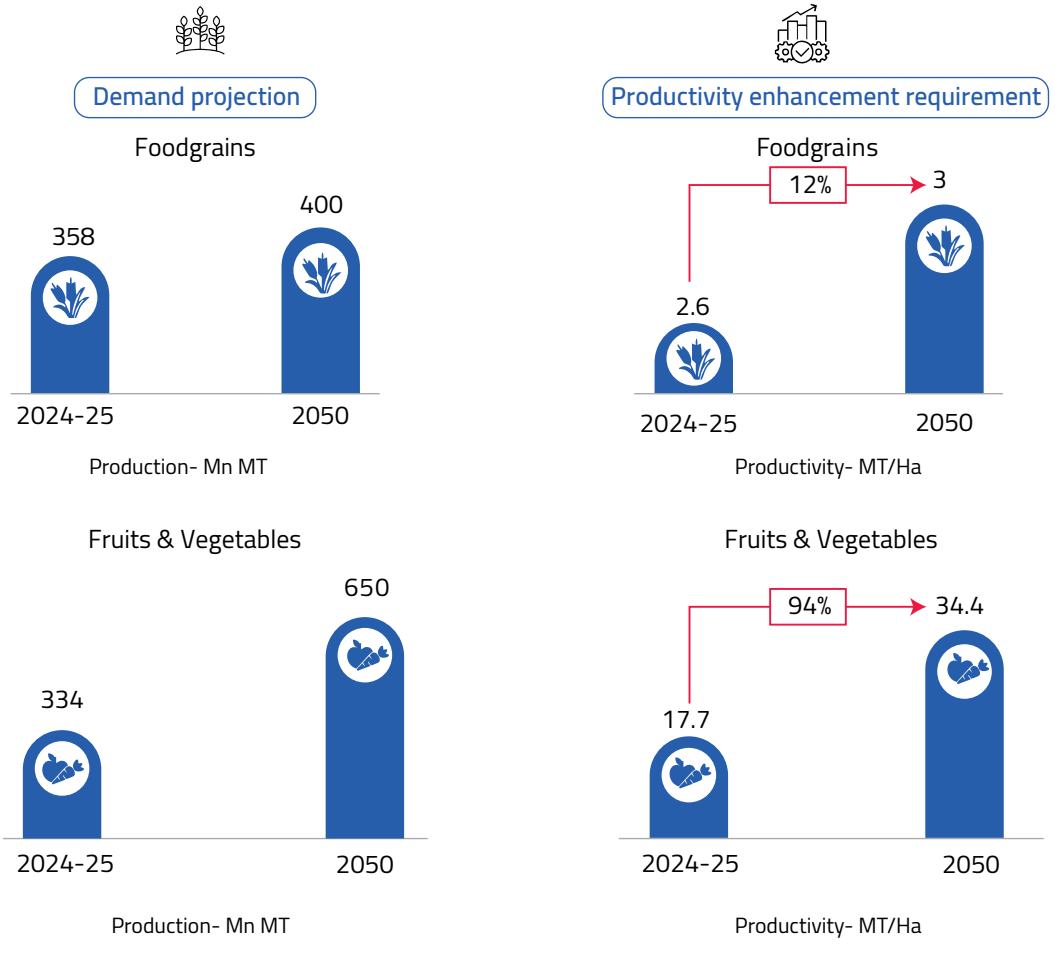
Source: FAOSTAT 2024

[12] FAOSTAT 2024

Overall, India's crop yields continue to fall short of global benchmarks across most major commodities. The underlying constraints include fragmented and economically unviable farm sizes, inconsistent access to irrigation, rising water stress, imbalanced fertiliser use, limited penetration of modern agronomy and extension services, and intensive soil degradation. These issues collectively cap yield potential and restrict the sector's ability to respond to growing food, feed, and export demand.

On the other hand, demand projections indicate that India's foodgrain production needs to increase from current levels of 358 Mn MT (2024-25) to 400 Mn MT by 2050, while fruit and vegetable production needs to grow from 334 Mn MT (2024-25) to over 650 Mn MT by 2050.[13] Much of this increase in production will need to come from productivity enhancement. This would mean that foodgrains productivity needs to increase from 2.6 MT/Ha (2024-25) to 2.9 MT/Ha by 2050, warranting a ~12% growth; while that for fruits and vegetables needs to significantly increase from 17.7 MT/Ha (2024-25) to 34.4 MT/Ha by 2050,[14] warranting a ~94% growth (refer exhibit 4).

Exhibit 4: Demand projections for foodgrains and fruits & vegetables



Source: ICAR vision 2050, Agriculture Statistics at a Glance 2024-25, MoA&FW

[13] ICAR-Vision 2050, Agriculture Statistics at a Glance 2024-25, MoA&FW

[14] Productivity for 2050 has been calculated by dividing the projected production (foodgrain + fruits & vegetables) of 2050 with the total area under cultivation (foodgrain + fruits & vegetables)-assuming land acreage remains the same

These productivity gains must be delivered even as agricultural workforce continues to shrink and environmental and sustainability concerns intensify. The share of the workforce engaged in agriculture is projected to decline sharply from the current 46%[15] to nearly 25% by 2050.[16] Further, climate change poses a serious long-term threat. A projected 2°C rise in average temperature and increasingly erratic rainfall patterns could reduce crop yields by nearly 7.2%,[17] impacting production stability and food availability.

Innovative crop nutrition-A catalyst for agricultural growth

Efficient crop nutrition continues to be a critical driver of agricultural productivity. From ancient practices of applying farmyard manure to the Green Revolution era where mineral fertilisers unlocked unprecedented yield breakthroughs, each major leap in agricultural output has been closely linked to an improvement in how crops access and utilise nutrients. However, the prevailing pattern of nutrient use in India is highly disproportionate. The imbalanced use of NPK has led to several challenges including declining nutrient use efficiency, soil degradation and a burgeoning subsidy burden. A detailed overview of the impact of imbalanced fertiliser use across these parameters is captured herewith.

1. Low nutrient use efficiency and declining response ratios

With a consumption of over 70 Mn MT (2024-25)[18], India is the second largest consumer of fertilisers globally.[19] Over the years, the use of fertilisers (NPK) in Indian agriculture has been on a steady rise, increasing from 0.29 Mn MT (of Nitrogen, Phosphorus and Potash (NPK) nutrients) in 1960-61 to 32.93 Mn MT in 2024-25.[20]

Consequently, the nutrient use intensity at the farm level has also undergone significant escalation. Nitrogen use increased from 1.4 kg/ha in 1960-61 to 101.6 kg/ha in 2024-25 witnessing a growth of 6.9% (CAGR). During the same period the use of Phosphorus (P) and Potassium (K) grew at 7.6% (CAGR) from 0.35 kg/ha to 38.5 kg/ha and 6.5% (CAGR) from 0.19 kg/ha to 10.9 kg/ha respectively.[21]

Parallel to this rise in fertiliser consumption, India's foodgrain production also witnessed growth, however at a much slower pace. Productivity gains stabilized over the years witnessing a 2% (CAGR), from 710 kg/Ha in 1960-61 to 2,601 kg/Ha in 2024-25 (refer exhibit 5).

[15] 2023-24, ICRIER-De-risking Fertiliser Supplies for India amid Rising Geopolitical Risks

[16] Farm mechanization – Trends and policy for its promotion in India

[17] ICAR Vision 2050, MoA&FW 2025

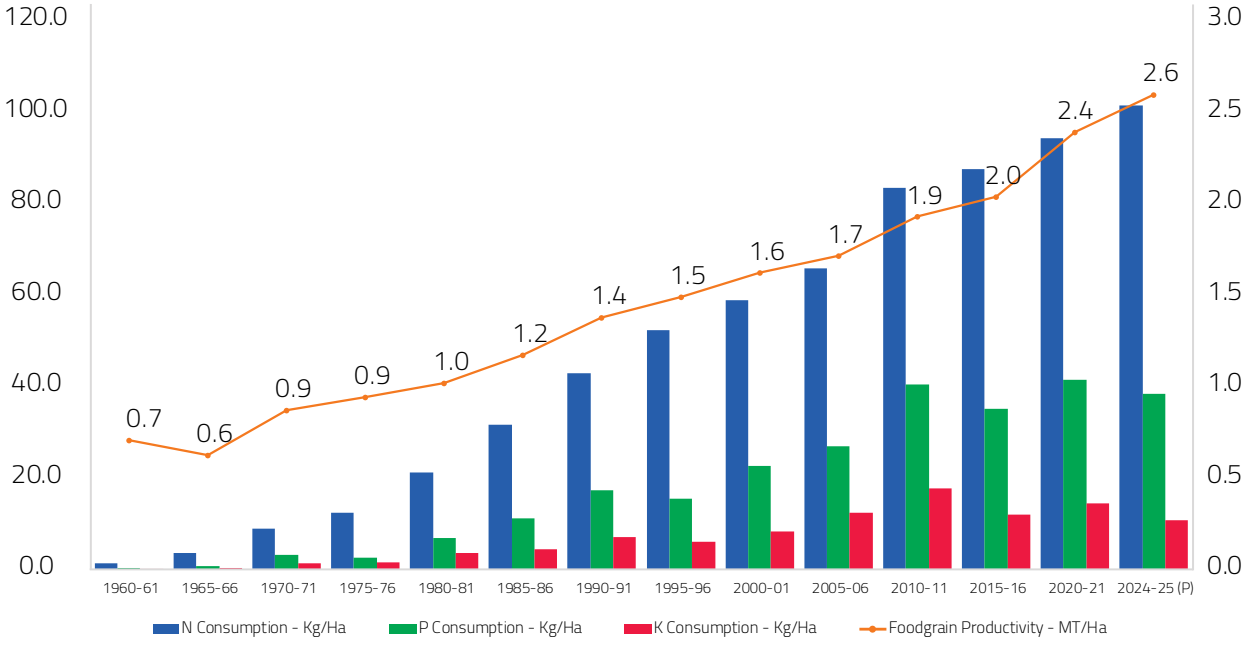
[18] equivalent to roughly 33 MMT of nutrients (nitrogen (N), phosphorus (P) and potash (K) nutrients)

[19] ICRIER-De-risking Fertiliser Supplies for India amid Rising Geopolitical Risks

[20] Agriculture Statistics at a Glance 2024-25, MoA&FW

[21] 70th Fertiliser Statistics 2024-25, The Fertiliser Association of India

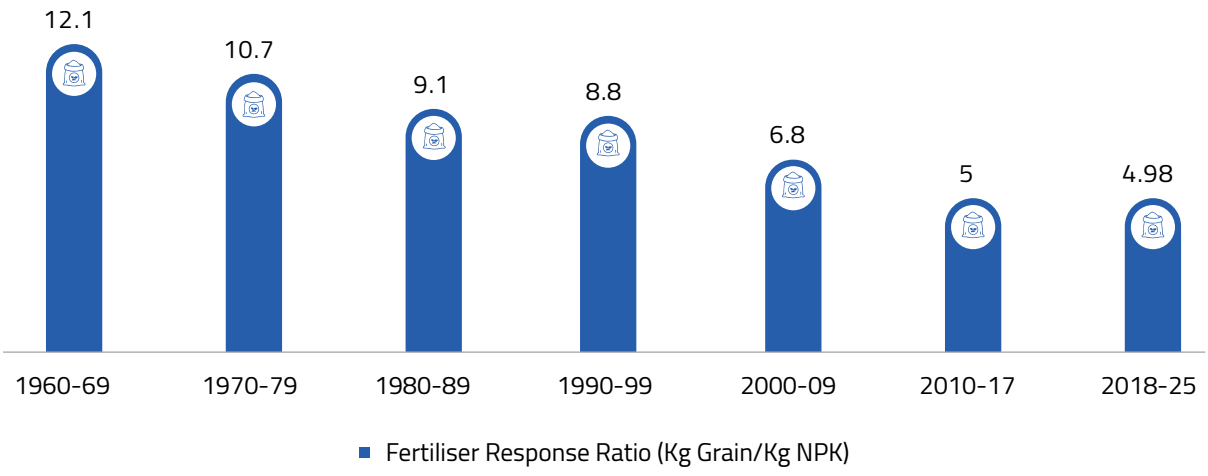
Exhibit 5: Fertiliser consumption (per hectare) trend by major nutrient vs foodgrain productivity



Source: FAOSTAT, 2024; 70th Fertilisers Statistics 2024-25, The Fertiliser Association of India

The fertiliser response ratio (measure of kilograms of grain produced per kilogram of NPK fertiliser applied) has also witnessed a significant decline over several decades. From 12.1 kg grain/kg NPK during 1960-69 the ratio decreased to 6.8 kg grain/kg NPK during 2000-09 and further declined to 4.9 kg grain/kg NPK during 2018-25[22] (refer exhibit 6).

Exhibit 6: Fertiliser response ratio (kg grain/kg NPK) over decades in India



Source: ICRIER-Healing Soils in India

[22] https://icrier.org/pdf/Healing-Soils-in-India.pdf / Biswas and Sharma (2008); Chaudhari et al. (2015), Chaudhari (2019) and Katyal (2019)

2. Soil degradation

Over the decades, reduced use of organic manures and injudicious use of inorganic fertilisers have caused a decline in soil organic matter and nutrient mining from soils. Farmers often apply high doses of nitrogen (urea) but neglect phosphorus, potassium and micronutrients. Moreover, despite high usage of urea, 73%[23] of India's soils remain deficient in nitrogen primarily due to severe nitrogen leaching, volatilization and low soil carbon. This inadequate and imbalanced fertilization leads to secondary nutrient deficiencies and gradually depletes soil fertility. Widespread deficiencies of zinc, sulfur, and boron have also been observed in Indian soils due to imbalanced NPK use without micronutrient replenishment (refer exhibit 7).

Exhibit 7: Nutrient deficiency in Indian soils



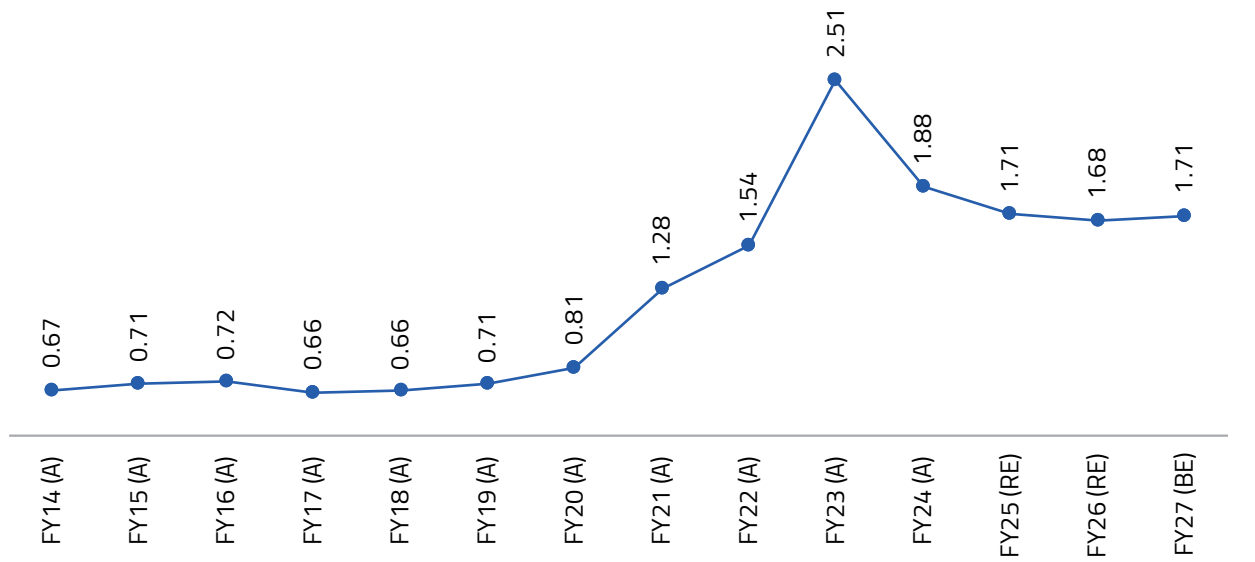
Source: https://soilhealth.dac.gov.in/nutrient-dashboard, MoA&FW 2025-26, accessed on May 28, 2026

[23] https://soilhealth.dac.gov.in/nutrient-dashboard, MoA&FW 2025-26, Based on samples tested under Soil Health Card Scheme, accessed on May 28, 2026

3. Burgeoning subsidy burden

India's fertiliser use is supported by one of the world's largest subsidy programs. Fertiliser subsidies have kept the farmer purchase prices low (urea is sold at a fixed price of INR 242 per 45 kg bag, well below cost),[24] with the government reimbursing companies for the difference. Currently, around 80–85% of urea's production cost in domestic plants is subsidized, compared to ~45% for phosphatic fertilisers (calculated based on import parity price) and a mere 5% for K fertilisers (Kharif, 2025). This distorted pricing structure has created a significant price disparity between urea and other N, P and K fertilisers, fuelling the excessive use of urea for decades.[25]

Exhibit 8: Fertiliser Subsidy Expenditure (INR trillion)



Source: Department of Fertilizers, Ministry of Chemicals & Fertilizers, GoI

Over time, rising consumption and high global prices have drastically increased the subsidy bill. In 2022-23, the fertiliser subsidy expenditure hit a record high of INR 2.25 lakh crore[26]. This was far above initial budget projections and required additional allocations. For 2026-27, the subsidy has been budgeted at INR 1.71 lakh crores which is 3.2% of the Union Government's budget, exceeding the agriculture budget share of 2.6%. Of the total INR 1.71 trillion fertiliser subsidy budget, around 68% (INR 1.17 trillion) has been allocated to urea alone, while the remaining INR 0.54 trillion is for nutrient-based subsidies.[27] The trend in recent years shows annual subsidy outlays in the range of INR 1.5–2 lakh crores (refer exhibit 8). This subsidy burden could be fiscally unsustainable in the long run while also incentivizes overuse of fertilisers (especially urea). Moreover, if geopolitical tensions and supply disruptions persist, the subsidy burden could potentially cross INR 2.5 trillion for FY 2026-27.[28]

[24] Cost is approx. INR 35-40/kg, 69th Fertiliser Statistics 2023-24, The Fertiliser Association of India

[25] https://icrier.org/pdf/Healing-Soils-in-India.pdf

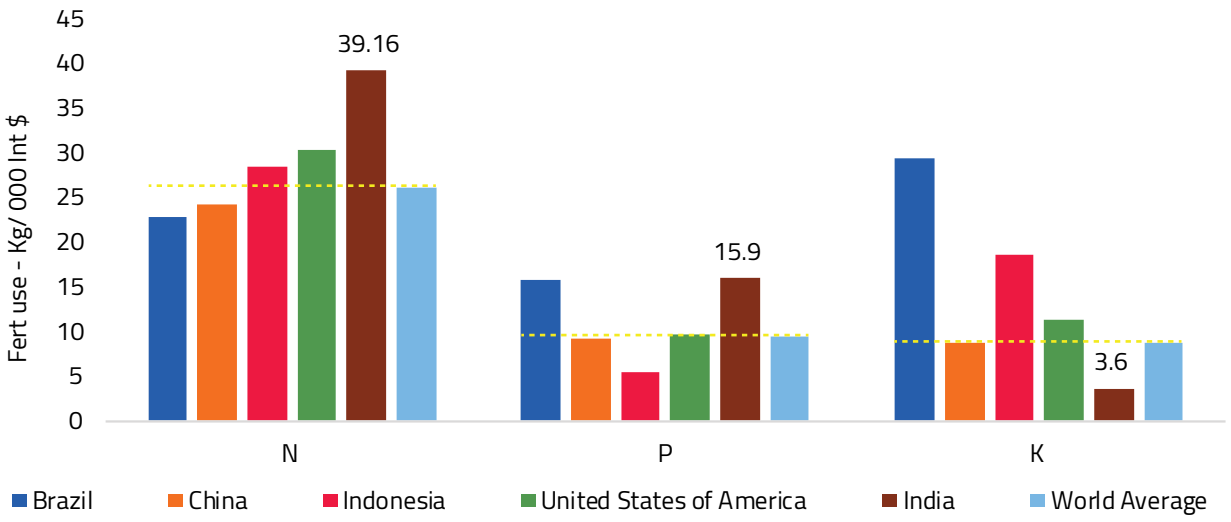
[26] Notes on Demand of Grants, Department of Fertiliser, Ministry of Chemicals and Fertiliser

[27] PRS Legislative Research, Demand for Grants 2026-27 Analysis, https://prsindia.org/files/budget/budget_parliament/2026/DfG_Analysis_2026-27-Agriculture.pdf

[28] ICRIER-Ensuring-India-s-Fertiliser-Security-Amid-Rising-Geopolitical-Risks.pdf

India's fertiliser use (especially N and P) per value of agricultural production has also been relatively higher that countries like USA, Brazil and China — implying that India uses larger amounts of fertilisers to produce the same economic value of agricultural output compared to other countries (refer exhibit 9).

Exhibit 9: Comparison of fertiliser use per value of agricultural production (Kg/ 000 Int$)



Source: FAOSTAT 2023

Reducing inefficient fertiliser consumption through improved fertiliser use efficiency could unlock significant fiscal and productivity gains for India. A modest 8-10% improvement in use efficiency, achieved through innovative crop nutrition could potentially generate ~INR 9,000-10,000 crores in subsidy savings, annually.[29] These savings could be strategically redirected to fund productivity enhancing and sustainable agricultural practices. Every percentage increase in crop productivity has the potential to translate into an incremental ~ INR 33,000 crores addition to the agricultural GVO.[30]

This shift becomes more important, as India continues to rely on imports for several critical fertiliser products and raw materials. Approximately 20% of its urea requirement, and nearly 50% of di-ammonium phosphate (DAP) consumption, originates from the Gulf region. While almost 100% of its muriate of potash (MOP) requirement is primarily sourced from Russia, Canada, and other international suppliers[31].

As a result, India's fertiliser sector is not merely import-dependent; it is strategically linked to global energy, mining, and logistics networks. Consequently, geopolitical disruptions rapidly translate into higher input costs, supply uncertainties, increased subsidy requirements, and inflationary pressures across the agricultural economy.

Thus, India needs to urgently move towards a more balanced, innovative, scientific and sustainable approach towards nutrient usage in agriculture. This new "Innovative Plant Nutrition" approach would need new fertilisers, technologies, and practices that can deliver nutrients to crops more efficiently, effectively, and sustainably.

[29] YES BANK Analysis

[30] 2023-24 crop GVO at current prices, YES BANK Analysis

[31] ICRIER-De-risking Fertiliser Supplies for India amid Rising Geopolitical Risks

2 The Global Fertiliser Crises: A Call for Transformative Action



India's fertiliser sector is deeply integrated into global trade, energy, and logistics networks, making it highly sensitive to international market dynamics. With annual fertiliser consumption exceeding 70 million tonnes[32], India is among the world's largest fertiliser consumers and relies on a complex global ecosystem to sustain its requirements. Recent estimates suggest that nearly 68-70% of the country's fertiliser value chain is linked to foreign sources[33], reflecting substantial dependence on imported fertilisers, raw materials, and feedstocks.

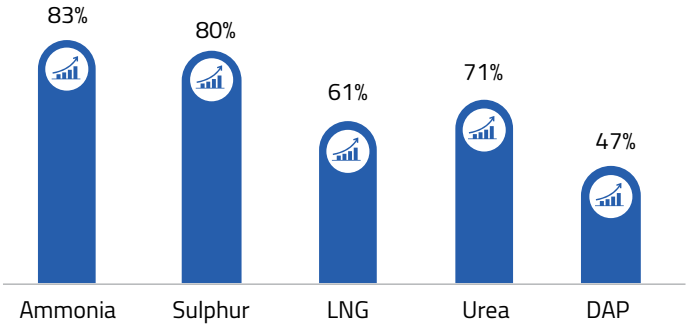
This dependence is particularly pronounced across critical nutrients and inputs. India imports approximately 20% of its urea, 50% of di-ammonium phosphate (DAP), and 100% of muriate of potash (MOP) requirements. Moreover, domestic fertiliser production is itself reliant on imported feedstocks, with nearly 85% of the natural gas used in urea manufacturing sourced from overseas markets[34]. As a result, disruptions in global supply chains, energy markets, or trade routes rapidly cascade through the fertiliser ecosystem, affecting input availability, increasing production costs, straining subsidy expenditures, and ultimately impacting farm productivity and food security.

This vulnerability has become increasingly evident amid recent geopolitical tensions and supply chain disruptions, which have reinforced the need to strengthen India's fertiliser security and reduce exposure to external shocks.

The Middle East accounts for nearly 80% of India's ammonia and sulphur imports, 60% of LNG and urea imports, and close to half of DAP and rock phosphate supplies (refer exhibit 10). Thus, the disruption in the region's trade routes and energy supplies has had implications on input costs, subsidy outlays, and in the longer term, could impact availability as well.

Prices for key fertiliser raw materials and finished products have also increased significantly. Global urea prices reportedly surged by nearly 65%, rising from around

Exhibit 10: Share of Middle east region to India's imports



Source: ICRIER- De risking fertiliser supplies for India amid rising geopolitical risks; Ensuring India's Fertiliser Security Amid Rising Geopolitical Risks

[32] India consumed about 70.7 million metric tonnes (MMT) of fertiliser products, equivalent to roughly 33 MMT of nutrients (nitrogen (N), phosphorus (P) and potash (K) nutrients).

[33] ICRIER-De-risking Fertiliser Supplies for India amid Rising Geopolitical Risks

[34] ICRIER-De-risking Fertiliser Supplies for India amid Rising Geopolitical Risks

USD 482 per tonne in late February 2026 to nearly USD 795 per tonne in early April. Phosphatic fertilisers have similarly come under pressure. International DAP prices increased from approximately USD 627 per tonne to nearly USD 720 per tonne, while the larger strategic concern lies in the supply of sulphur and ammonia—both critical inputs for phosphatic fertiliser production.[35]

Empirical evidence suggests that India imported 2.5 million tonnes of urea at prices 112% higher than before the conflict, while DAP imports totalling 1.35 million tonnes cost 38% more than pre-war levels. Natural gas, a crucial feedstock for fertiliser production, has also seen a sharp price rise, with procurement costs through open tenders increasing by 70-80%.[36]

The onwards price movement will now not only depend on the Strait of Hormuz, but the evolving export policies of the major non-gulf fertiliser suppliers. China, Russia, Egypt and Indonesia are the alternate suppliers for nitrogen and phosphates. Each of these countries have implemented some form of export quotas or restrictions, so as to protect their own domestic prices.

The Government of India has acted swiftly to address this crisis. To shield farmers from soaring international prices, the government expanded the Nutrient Based Subsidy (NBS) budget. For the Kharif 2026 season, the Cabinet fixed the P&K subsidy budget at INR 41,533.81 crore, which is INR 4,317 crore higher than the previous year.[37] While these emergency funds ensure affordable access for farmers, they highlight how sensitive the national budget is to sudden overseas shocks. If geopolitical tensions and supply disruptions persist, the subsidy burden could potentially cross INR 2.5 trillion for FY 2026-27.[38]

The Ministry of Agriculture and Farmers Welfare also launched the "Khet Bachao Abhiyan" in June. This is a nationwide, month-long awareness campaign launched to promote soil conservation, balanced fertiliser use, and sustainable farming. The initiative aims to restrict excessive use of inputs while boosting agricultural profitability and crop diversification.

The current crisis presents India an opportunity to reshape its fertiliser strategy, placing innovative crop nutrition at the centre of the country's efforts to strengthen productivity, profitability and resilience of Indian agriculture. The path forward lies not in returning to the status quo, but in leveraging this crisis to drive a more productive, sustainable, and globally competitive agricultural future.

[35] ICRIER-Ensuring-India-s-Fertiliser-Security-Amid-Rising-Geopolitical-Risks.pdf

[36] https://agriculture.economictimes.indiatimes.com/news/inputs-and-supply-chains/indias-fertiliser-demand-soars-as-global-conflict-disrupts-supply-chains/131443358

[37] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2250060&reg=48&lang=2

[38] ICRIER-Ensuring-India-s-Fertiliser-Security-Amid-Rising-Geopolitical-Risks.pdf

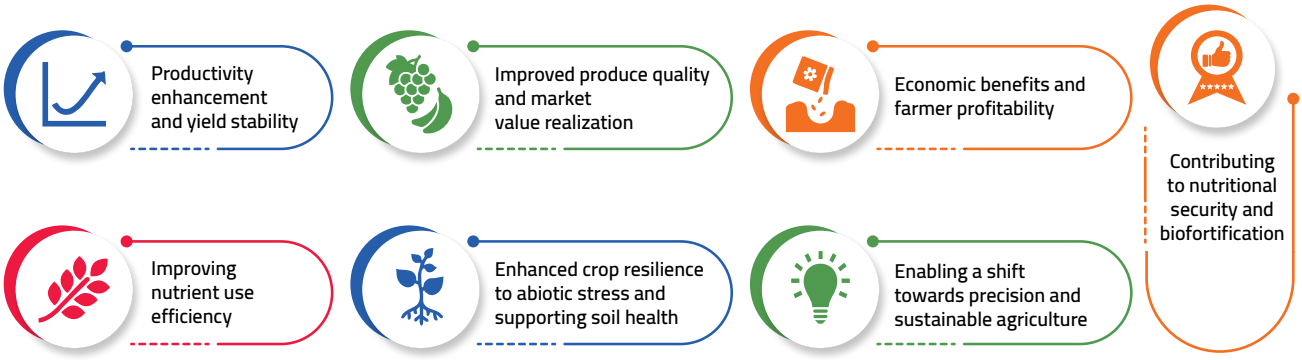
3 Innovative Crop Nutrition Landscape



Innovative crop nutrition shifts focus from quantity-driven fertilization to performance-driven nutrient management. It focuses on delivering the right nutrients, in the right form, at the right time, and through the right pathways to maximise uptake and utilisation by crops. By improving nutrient use efficiency, reducing losses, and strengthening crop physiology, these innovative nutrition solutions directly target the core productivity challenge confronting modern agriculture.

The urgency for innovation in the crop nutrition space is amplified by multiple structural pressures facing agriculture today. Some of these include degrading soil health, imbalanced nutrient application, rising input costs, climate stress, and growing sustainability expectations. In the Indian context, these pressures are especially acute, with declining response rates to conventional fertilisers and widespread micronutrient deficiencies limiting the yield potential realization across key crops. Innovative crop nutrition therefore becomes not incremental, but essential to sustaining productivity growth. Exhibit 11 captures key benefits of innovative crop nutrition.

Exhibit 11: Benefits of innovative crop nutrition



Source: Industry Sources

Productivity enhancement and yield stability

Innovative crop nutrition solutions improve nutrient availability and uptake efficiency, ensuring crops receive balanced nutrition aligned with growth stages. These solutions enhance root development, photosynthetic activity, and reproductive efficiency, translating into higher yields and improved crop uniformity.

Improved Nutrient Use Efficiency

Advanced nutrient formats enable controlled release and targeted delivery through fertigation & foliar application, minimizing losses from leaching, volatilization and soil fixation. This increases Nutrient Use Efficiency (NUE), allowing farmers to achieve higher output per unit of nutrient applied (refer exhibit 12).

Exhibit 12: Nutrient Use Efficiency (NUE) of different fertilisers

Fertiliser Type	NUE (%)
Urea	30-40%
Water soluble fertilisers*	80–95%
Liquid fertiliser*	80-95%
Controlled-release fertilisers	60-70%
Seaweed extracts (as a biofertiliser)	50-70%

*Through fertigation (for N&K)

Source: https://www.biochemjournal.com/archives/2025/vol9issue2/PartH/9-2-91-832.pdf, Tamil Nadu Agricultural University (TNAU)

Enhanced crop resilience to abiotic stress

- Biostimulants and specialty nutrients strengthen plant physiological processes, improving tolerance to drought, salinity and temperature stress. This stabilizes productivity and reduces yield variability under adverse climatic conditions.
- **Improved produce quality and market value realization**

  Innovative nutrition improves key quality parameters such as size, colour, shelf life and nutrient density. This is particularly critical for horticulture and export-oriented value chains, where quality directly influences price realization.
- **Reduced environmental footprint**

  India is the fourth largest emitter of Nitrous Oxide (N2O), a greenhouse gas 270 times more potent than CO_2.[39] The agriculture sector contributes 70% to these emissions,[40] mainly due to the application of synthetic fertilisers. India could reduce significantly reduce fertiliser related greenhouse gas emissions by adoption of innovative crop nutrition products.

[39] The United Nations Environment Programme (UNEP)

[40] Ministry of Environment, Forest and Climate Change

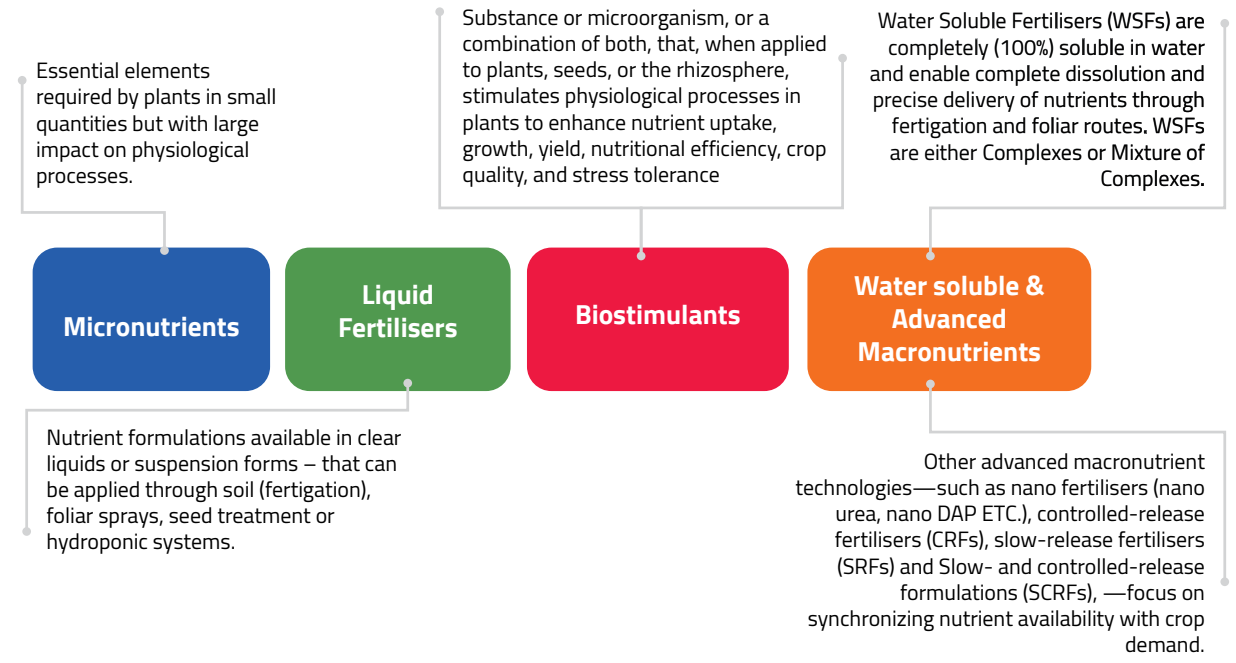
- **Economic benefits and farmer profitability**

  Innovative nutrition products, while sometimes higher in upfront cost, often prove cost-effective through quantity and yield gains. Improved efficiency and yield outcomes enhance return on input investment, while reduced nutrient wastage lowers overall input costs. This strengthens farm economics and supports sustainable intensification.

Thus, judicious use of fertilisers and embracing advanced solutions, can ensure that every rupee of nutrient applied yields maximum food, and every rupee of subsidy yields maximum value. This is why a paradigm shift towards innovative plant nutrition is timely and vital.

This chapter delves into specific innovative fertilisers, their benefits, market dynamics and evidence of impact. It examines four critical categories of innovative crop nutrition, including liquid fertilisers, biostimulants, micronutrients, and water-soluble fertilisers & other advanced macronutrient solutions (refer exhibit 13). Together, these categories[41] represent the next frontier of crop nourishment, offering a pathway to unlock higher productivity, strengthen farm economics, and build more resilient agricultural systems.

Exhibit 13: Key categories of innovative crop nutrition



Source: Industry Discussions, Fertiliser Control Order-1985

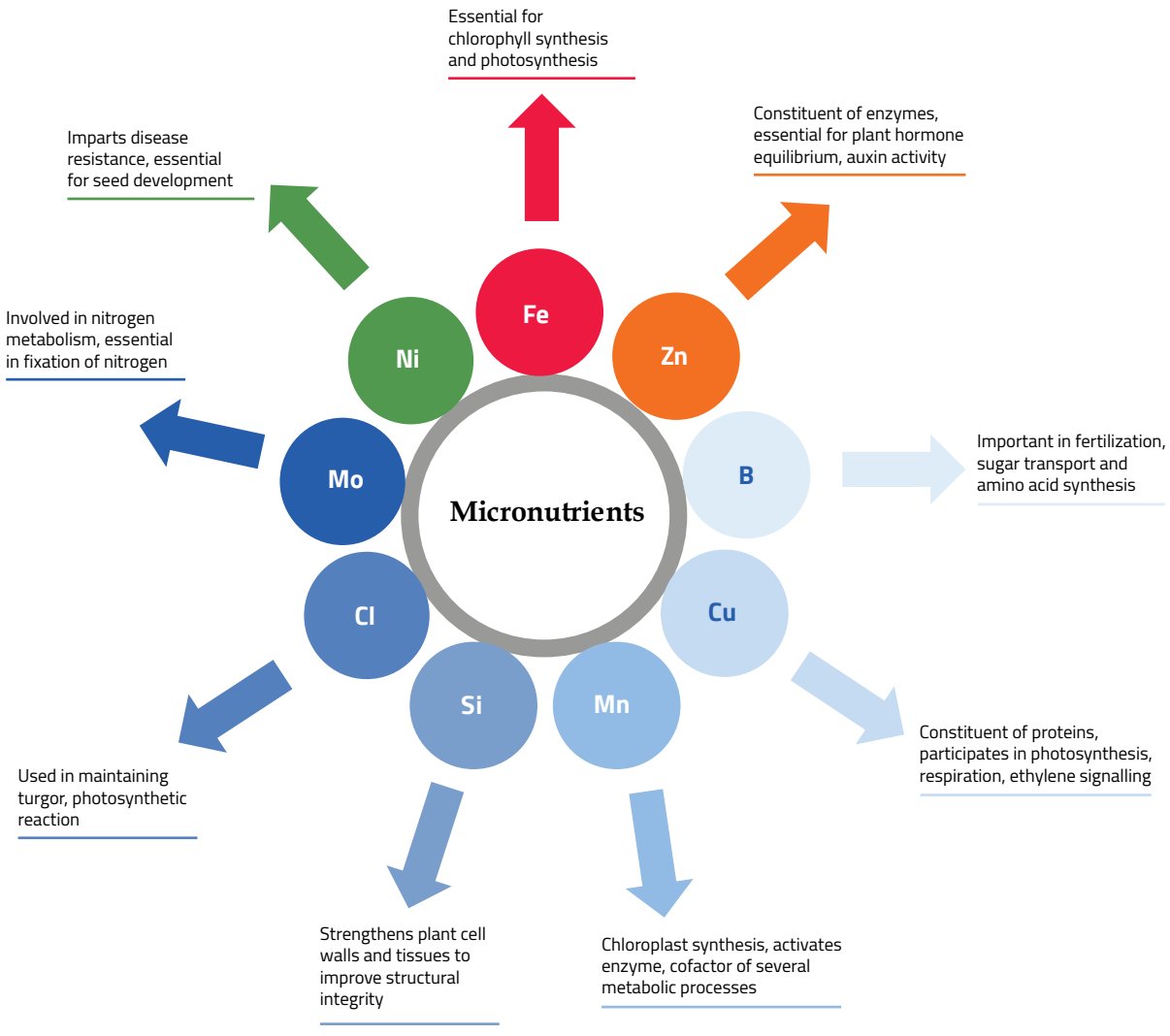
[41] There may be an overlap in the categories-on account of the form.

3.1 Micronutrients

3.1.1 Introduction

Micronutrients are essential elements required by plants in small quantities but with large impact on physiological processes. There are nine essential micronutrients required by the plants, namely Zinc (Zn), Iron (Fe), Manganese (Mn), Copper (Cu), Molybdenum (Mo), Boron (B), Chlorine (Cl), Nickel (Ni) and Silicon (Si[42]). Though each of these nutrients is required in trace amounts, they play a critical role in plant growth and development by facilitating key biochemical functions such as photosynthesis, nitrogen fixation and enzyme activity (refer exhibit 14).

Exhibit 14: The diverse role of micronutrients in plants



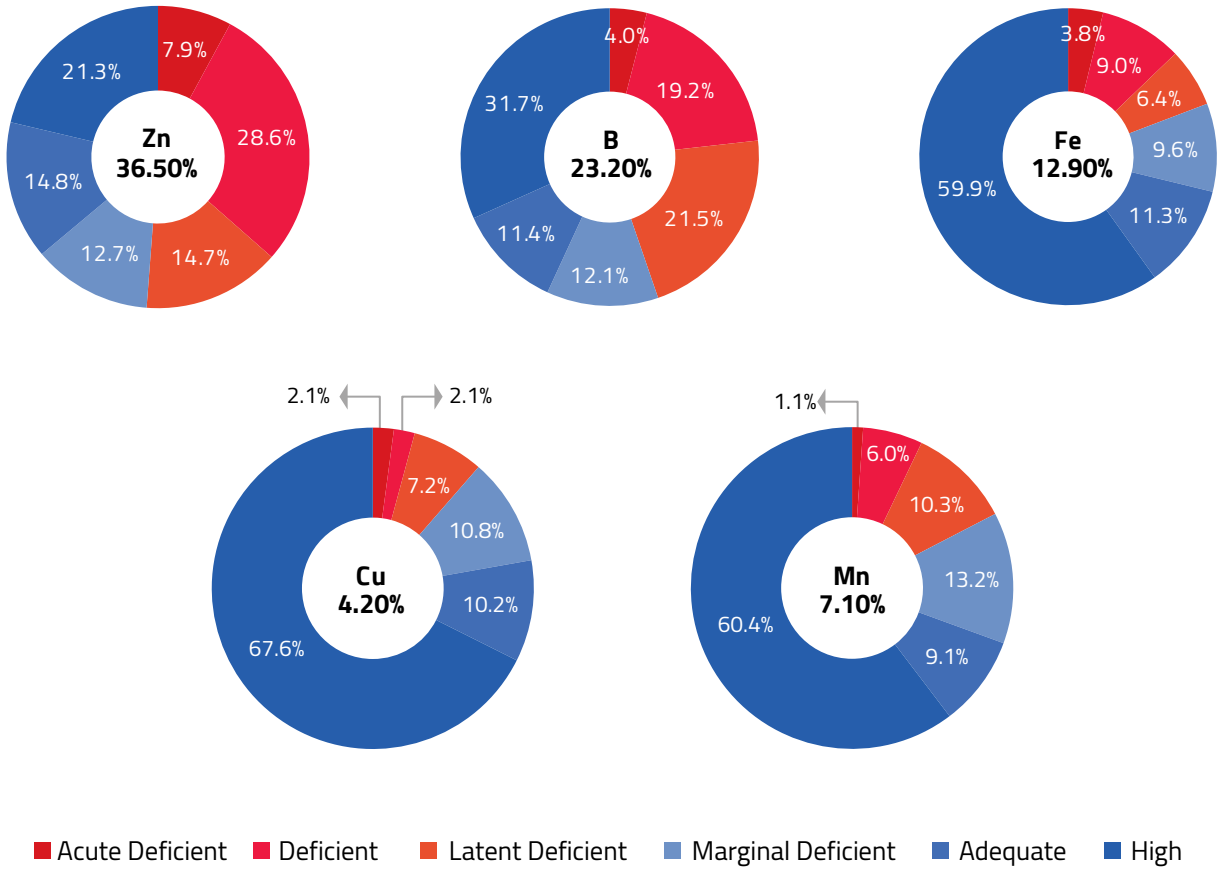
Source: Shukla, A.K., Behera, S.K. and Singh, G., 2021. Micronutrient Fertilisers in Indian Agriculture–Product Profile, Availability, Forecast, and Agronomic Effectiveness. Indian Journal of Fertilisers, 17(4), pp.348-360, Industry sources, YES BANK Analysis

[42] Silicon is the latest addition to micronutrients basket

Micronutrient deficiencies represent one of the most persistent and underestimated constraints in Indian agriculture. Often referred to as "hidden hunger", micronutrient gaps suppress yield potential, reduce nutrient use efficiency, and compromise crop quality, even in fields receiving adequate macronutrients.

Intensive cultivation, high-yielding varieties, imbalanced NPK usage (especially excessive nitrogen), declining organic matter, and limited replenishment have progressively depleted micronutrient reserves in Indian soils. As a result, micronutrient deficiencies have shifted from being localized agronomic issues to systemic productivity constraints across major cropping systems. Studies indicate that on an average 36.50% of Indian agricultural soil is deficient in Zn, 12.90% in Fe, 4.20% in Cu, 7.10% in Mn and 23.20% in B (refer exhibit 15).[43]

Exhibit 15: Micronutrient deficiency in India



Source: hukla, A.K., Behera, S.K., Prakash, C., Patra, A.K., Rao, C.S., Chaudhari, S.K., Das, S., Singh, A.K., Green, A. (2021). Assessing multi-micronutrients deficiency in agricultural soils of India. Sustainability 13, 9136.

In India, micronutrients majorly fall under Schedule 1(g) (Micronutrients) and 1(h) (Fortified fertilisers) of the Fertiliser Control Order (FCO). Some micronutrients also fall under 1(k) (Liquid fertilisers), Clause 20B (Customized fertilisers) and Schedule-VII (Nano fertilisers) of FCO.

A new category known as "Customized Fertilisers" (CFs) was introduced under Clause 20B of the FCO in 2009, to address the growing challenge of multi-nutrient deficiencies. Additionally, several multi-micronutrient mixture formulations have been notified by State Governments. While single micronutrient fertilisers are standardized

[43] Shukla et al. (2021), The number does not match exhibit 7 because of variation in sources.

across all states under the FCO, micronutrient mixtures, comprising two or more nutrients, are state-specific and notified based on local crop and soil requirements. Exhibit 16 provides a snapshot of the different categories of micronutrient fertilisers.

Exhibit 16: Select Micronutrient products under various categories

Straight inorganic salts

21 type of fertilisers including
- Zinc Sulphate
- Manganese Sulphate
- Borax
- Ferrous Sulphate

Straight - Chelated

- Chelated Zinc as Zinc-EDTA
- Chelated Iron as Fe-EDTA
- Chelated Zinc as Zn-HEDP

Multi-micronutrient Mixture

More than 100 grades were notified cumulatively through various states

Fortified fertilisers

34 types of fertilisers including
- Zincated Urea
- Boronated DAP
- Zincated NPK

Customised fertilisers

28 types of fertilisers including 19 fertilisers having some composition of micro-nutrients

Liquid fertilisers

- Chelated Zinc as Zinc-Glycine
- Chelated Boron as Boron-Glycine
- Fortified NK, NP and NPK solutions

Source: FAI, The Fertiliser (Inorganic, Organic and Mixed) (Control) Order, 1985

3.1.2 Use & Application

Micronutrient fertilisers provide a targeted and efficient approach to improving soil fertility, boosting crop yields, and promoting sustainable farming by supplementing specific nutrient deficiencies. They are typically applied either in combination with, or as additives to, Nitrogen, Phosphorus, and Potassium (NPK) fertilisers.

Micronutrients are applied using multiple routes, depending on crop, soil conditions, irrigation infrastructure, and the nature of deficiency. The key application methods include:

- **Soil application:** Soil application remains the most widely adopted method for supplying micronutrients, particularly in field crops where deficiencies are widespread. These are applied at the time of land preparation or sowing and incorporated into the soil, allowing gradual uptake by plant roots throughout the crop growth cycle. Zinc sulphate is the most commonly soil-applied micronutrient in India, especially in rice–wheat systems, followed by boron in oilseeds and pulses. Soil application is particularly effective in correcting chronic deficiencies and provides residual benefits over multiple seasons. However, its effectiveness is strongly influenced by soil properties such as pH, texture and organic matter content.

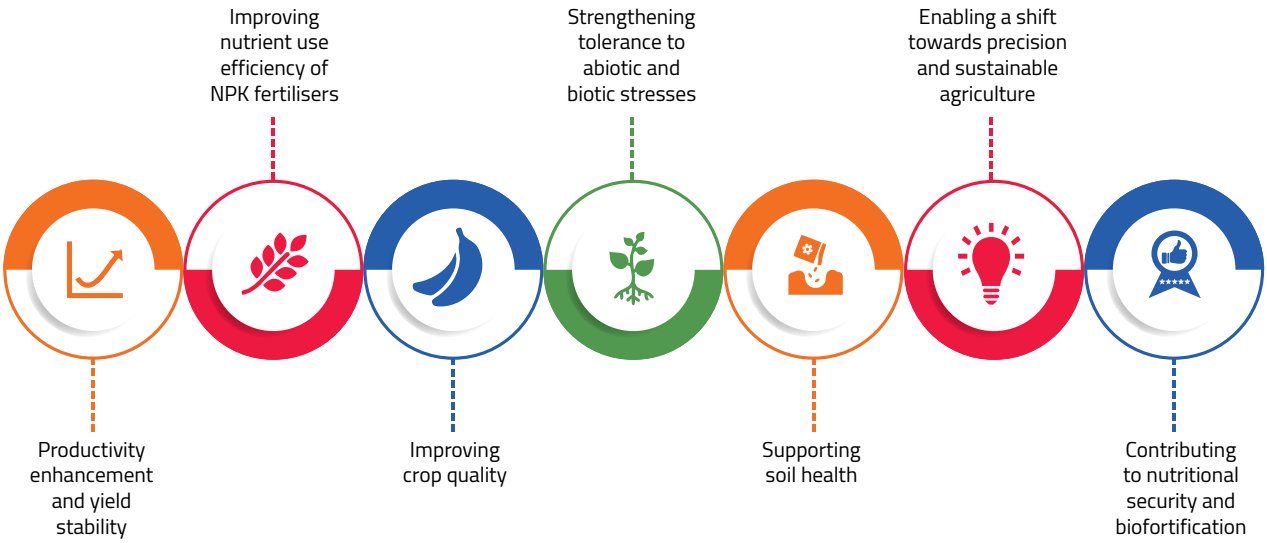
- **Foliar application:** Foliar application has emerged as a highly effective strategy for correcting micronutrient deficiencies during the standing crop phase, particularly where soil-related constraints limit nutrient availability. Foliar application enables rapid absorption and immediate physiological response, making it useful during periods of peak nutrient demand such as flowering, grain filling and fruit development. In cereals, foliar sprays of zinc and iron are commonly used to overcome deficiencies that restrict tillering and grain formation. In oilseeds and horticultural crops, foliar application of boron and multi-micronutrient formulations plays a critical role in improving flowering, fruit set and produce quality.

- **Seed treatment and seed priming:** Seed treatment and seed priming with micronutrients present a targeted and cost-effective approach to improving early crop establishment and vigour. Seeds are coated or soaked in dilute micronutrient solutions prior to sowing, ensuring that young seedlings have immediate access to essential nutrients during the critical early stages of growth. This is commonly practiced in pulses, where treatment with molybdenum and zinc enhances nodulation and nitrogen fixation, leading to improved plant growth and higher protein content. In cereals and oilseeds, seed treatment with zinc and boron has been shown to improve germination, root development and stress tolerance.

- **Fertigation through drip irrigation:** With the expansion of micro irrigation infrastructure in India, liquid and chelated micronutrients are increasingly being applied through fertigation. This application method ensures uniform delivery to the active root zone, higher uptake efficiency and compatibility with precision nutrition schedules. Fertigation is especially relevant for horticultural crops, vegetables and protected cultivation, where nutrient requirements are high and yield quality parameters are critical. Chelated forms of iron and zinc are commonly used in fertigation to overcome soil fixation issues and ensure sustained nutrient availability.

3.1.3 Advantages of micronutrients

Exhibit 17: Advantages of micronutrients



Productivity enhancement and yield stability

One of the most significant advantages of micronutrients lies in their ability to unlock latent yield potential in crops. Even when macronutrients such as nitrogen, phosphorus and potassium are applied adequately, deficiencies of micronutrients can severely restrict crop response, leading to yield stagnation. Micronutrients act as critical cofactors in enzymatic and metabolic processes, enabling efficient photosynthesis, protein synthesis and energy transfer within the plant. Their application therefore improves the effectiveness of existing fertiliser use rather than substituting it. In Indian cropping systems, where yield gaps remain substantial, the judicious use of micronutrients has consistently resulted in measurable yield gains and improved yield stability across seasons.

Improving nutrient use efficiency of NPK fertilisers

Micronutrients play a central role in enhancing nutrient use efficiency, particularly for nitrogen. Elements such as zinc, iron and molybdenum are directly involved in nitrogen metabolism, assimilation and enzyme activation. When these nutrients are deficient, a significant portion of applied nitrogen remains unused or is lost to the environment through volatilisation, leaching and runoff. By correcting micronutrient deficiencies, crops are able to absorb and utilise macronutrients more effectively, resulting in higher output per unit of fertiliser applied.

Improving crop quality

Beyond yield enhancement, micronutrients play a decisive role in improving the physical, nutritional and commercial quality of agricultural produce. Zinc and iron influence grain protein content and micronutrient density, boron affects fruit and seed development, while copper and manganese contribute to colour, firmness and shelf life. In horticultural crops, adequate micronutrient nutrition translates into better fruit size, uniformity, colour development and reduced physiological disorders, all of which directly impact market realisation. As Indian agriculture increasingly shifts towards high-value crops, exports and quality-conscious domestic markets, the role of micronutrients in quality enhancement becomes a critical economic advantage for farmers.

Strengthening tolerance to abiotic and biotic stresses

Micronutrients significantly enhance crop resilience to abiotic stresses such as drought, heat, salinity and cold, as well as biotic stresses from pests and diseases. Zinc and manganese are involved in antioxidant enzyme systems that protect plant cells from oxidative stress, while copper plays a role in improving disease resistance. Adequate micronutrient nutrition helps crops maintain physiological functions under stress conditions, reducing yield losses during adverse weather events. In the context of increasing climate variability in India, this stress-mitigating function of micronutrients provides a critical buffer against production risk.

Supporting soil health

The advantages of micronutrients extend beyond the crop to the soil ecosystem. Balanced micronutrient application supports healthy root growth, stimulates beneficial microbial activity and improves the overall biological functioning of soils. When integrated with organic matter and balanced fertilisation practices, micronutrients contribute to the restoration of soil fertility that has been degraded by decades of nutrient mining and imbalanced fertiliser use.

Enabling a shift towards precision and sustainable agriculture

The use of micronutrients aligns closely with the broader transition towards precision, efficiency-driven and sustainable agriculture. Advances in soil testing, fertigation, foliar nutrition and customised formulations allow micronutrients to be applied in a targeted and site-specific manner, minimising waste and environmental impact. As Indian agriculture seeks to balance productivity growth with sustainability imperatives, micronutrients provide a scientifically grounded pathway to achieve more with less.

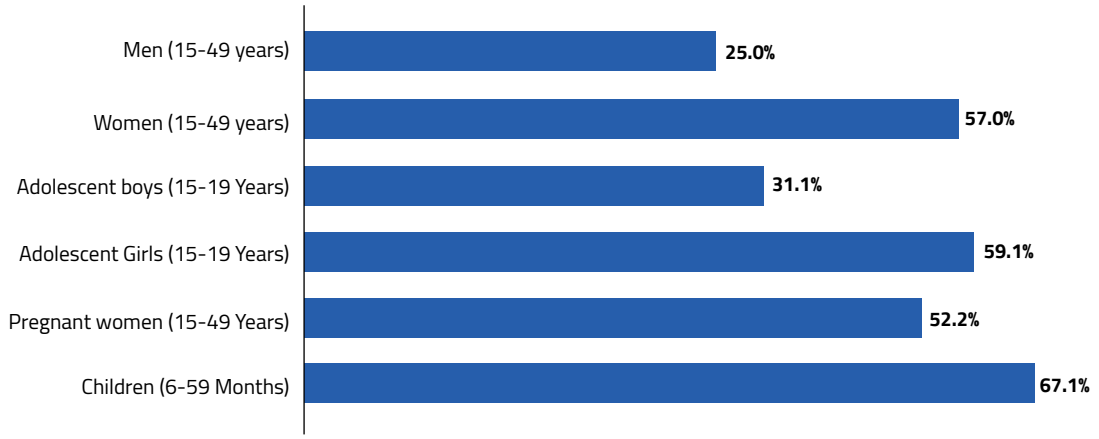
Contributing to nutritional security and biofortification

Micronutrients also play an indirect but important role in improving human nutrition through agriculture. Adequate zinc and iron nutrition in crops increases their concentration in edible plant parts, contributing to dietary micronutrient intake. This biofortification effect is especially relevant in India, where deficiencies of iron and zinc remain widespread among the population. According to the 5th National Health Survey (2019-21), 67% children (aged 6-59 months), 57% women (15-49 years) and 52% pregnant women (15-49 years) were reported anaemic (refer exhibit 18). By improving the micronutrient content of staple crops, agricultural micronutrient management contributes to broader nutritional security objectives alongside productivity gains.

The intake of micronutrients in daily diet in India is far from satisfactory and largely less than 50% Recommended Dietary Allowance (RDA) is consumed by over 70% of population. The loss due to micronutrient deficiency costs India 1% of its GDP. This amounts to a loss of INR 27,720 crore per annum in terms of productivity, illness, increased health care costs and death.

Source: National center for biotechnology information

Exhibit 18: Status of Anaemia in India as per the National Health Survey (2019-2021)



Source: 5th National Health Survey 2019-2021

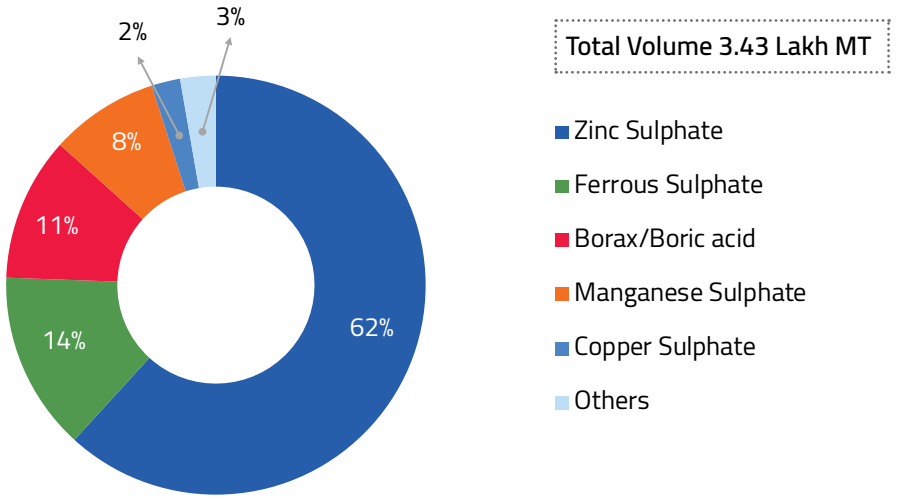
3.1.4 Market Dynamics

India represents one of the largest micronutrient fertiliser markets globally, driven by high prevalence of soil deficiencies, large acreage and rapid growth in horticulture production.

India's micronutrient fertiliser market is estimated at 3.43 lakh MT, valued at around USD 595 Mn (in FY2025). The market has been estimated to be growing at a CAGR of 8-10% (by value) between FY20 and FY25.[44] Growth in the micronutrients segment has been significant on account of widespread micronutrient deficiencies in Indian soils, changing farm dynamics (multi cropping, high value agriculture) and increased awareness amongst stakeholders. Within the micronutrients market, Zinc (Zinc Sulphate) dominates the market with a share of around 62%, followed by iron and boron (by vol.) (Refer exhibit 19).

[44] Specialty Fertiliser and Micronutrient Statistics 2024-25, Fertiliser Association of India (FAI), Industry Discussions, YES BANK Analysis

Exhibit 19: Contribution of various micronutrients to total micronutrient consumption during 2024-25



Source: Specialty Fertiliser and Micronutrient Statistics 2024-25, Fertiliser Association of India (FAI), Industry Discussions
YES BANK Analysis

Looking ahead, the market is projected to grow at a faster pace estimated at 13-15% and reach USD 1,300 Mn by FY30. Growth is expected to be strongest in zinc and boron-based products, followed by multi-micronutrient mixtures, with emerging traction in crop and soil specific solutions. The chelated segment is expected to grow faster at about 18-20% on account of smaller consumption base at present, but an increasing demand from the farmers due to rising awareness and visible, measurable positive results on field.[45]

The key demand hotspots for micronutrients in India are:

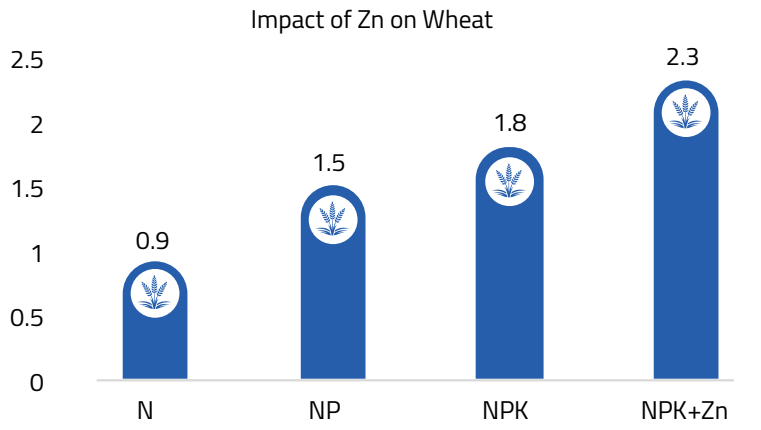
- Rice: wheat growing belts like Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, West Bengal as Zinc deficiency is endemic in rice–wheat systems and Zn application improves tillering, grain filling and NUE. The Indo-Gangetic plains remain highly deficient in Zn and hence has high demand.
- Oilseeds and pulses producing regions: Maharashtra, Rajasthan, Madhya Pradesh, Karnataka, as boron and molybdenum remain critical for flowering and nodulation.
- Horticulture and high-value crops producing region like Maharashtra, Karnataka, Tamil Nadu as calcium, boron, zinc and iron strongly influence fruit set, size, colour and shelf-life.
- Plantation crops and sugarcane: Long-duration crops deplete micronutrients and hence regular foliar and soil micronutrient schedules are now becoming a standard practice. Also, in Sugarcane, micronutrients are critical for metabolic activity, particularly in early growth and tillering.[46]

[45] IMMA-YES BANK Report:: Micronutrients-The Make in India Opportunity
[46] TNAU, http://www.agritech.tnau.ac.in/expert_system/sugar/nutrientmanagement.html

3.1.5 Evidence of impact

- Studies on impact of Zinc on 26 rice cultivars put forth that on an average, grain yields of different rice cultivars increased by 29% and 22% with soil + foliar and only soil application of Zn, respectively.[47]
- Experiments on application of Zn on wheat crop in India have shown over 20% yield gain.[48] (refer exhibit 20)
- Application of boron was found to have significantly influenced the yield of Indian mustard by improving the yield attributing characters. The yield increase was to the tune of 35-39%.[49]
- On the basis of the research findings of the All India Coordinated Research Project (AICRP) on Micronutrients in Soils and Plants (ICAR-IISS, Bhopal), significant improvements in the yield and quality of crops across India have been achieved through the strategic application of micronutrients, particularly Zinc (Zn), Boron (B), Iron (Fe), and combined micronutrient mixtures.

Exhibit 20: Impact of Zn on yield gains in wheat



Source: Tandon (1995), Cakmak (2006)

  - At Pantnagar, foliar spray of micronutrients in Basmati rice-wheat systems increased grain yield of Basmati rice by 13.1–15.8% over the control. A subsequent wheat crop showed a 19.6% yield increase (AICRP 2009).[50]
  - Application of Recommended Dose of Fertilisers (RDF) + Amino Acids (AM) @ 1 kg/ha + Biofertilisers resulted in the highest grain yield (1866 kg/ha) and increased protein content (21.87-23.46%) in Chickpea (Sahu & Singh 2014).[51]
  - In West Bengal, Zn application (5 Kg/Ha basal + 0.5% foliar spray) at the maximum tillering stage increased rice yield by 11-21%. Combined application of B and Zn along with FYM (5MT/Ha) for potato increased yield by 12-27%. Application of Zinc (5 Kg/Ha), Sulphur (40 Kg/Ha), and FYM (5MT/Ha) increased groundnut pod yield by ~59% over the control (Hazra 2025).[52]

[47] Bholanath saha, sushanta saha, gora chand hazra, susmit saha, nirmalendu basak, anupam das, & biswapati mandal. (2001). impact of zinc application methods on zinc concentration and zinc-use efficiency of popularly grown rice (oryza sativa) cultivars. indian journal of agronomy, 60(3), 391-402

[48] Periyamuthu, Kumararaja & Premia, O & Kandpala, B. (2015). Application of boron enhances Indian mustard (Brassica juncea) productivity and quality under boron deficient calcareous soil in semi-arid environment. Ecology, Environment and Conservation. 21. S249-S254

[49] https://www.researchgate.net/publication/289893512_Application_of_boron_enhances_Indian_mustard_Brassica_juncea_productivity_and_quality_under_boron_deficient_calcareous_soil_in_semi-arid_environment

[50] https://www.gbpuat.res.in/uploads/aicrp/19%20AICRP%20-%20MICRONUTRIENTS.pdf

[51] Sahu, S., & Singh, P. (2014). effect of micronutrients and biofertilizer inoculation on grain yield, protein content, micronutrients content and economics of chickpea

[52] https://www.bckv.edu.in/index.php/en/aicrp-on-micro-secondary-nutrients-pollutant-elements-in-soils-plants-en#

3.2 Liquid Fertilisers

3.2.1 Introduction

Liquid fertilisers are nutrient formulations available in clear liquids or suspension forms – that can be applied through soil (fertigation), foliar sprays, seed treatment or hydroponic systems. Liquid fertilisers can be broadly classified into:

1) Single Nutrient Liquid fertilisers-For providing a particular nutrient during its peak requirement stage in a given crop or for deficiency corrections.

2) NPK Liquid Blends / NPK Liquid Blends enriched with micros-Balanced or crop-specific, stage-specific formulations for delivering primary nutrients (with/ without micros) in high NUE form.

3) Multi-Micronutrient Liquid fertilisers-For tackling hidden hunger in crops and unlocking productivity.

Liquid fertilisers can be either in the form of True Solutions (Clear Liquids), Suspension Concentrates, Suspensions, Gels or Oil Dispersed (OD), each offering unique properties that cater to diverse cropping needs and soil conditions. Clear liquids, being true solutions, ensure uniform nutrient availability, while suspension fertilisers combine the benefits of high nutrient concentration with flexibility in application and offer a long-term feeding effect. Together, these formulations provide farmers with a versatile solution to meet specific crop requirements across different stages of growth.

3.2.2 Use & Application

Liquid fertilisers can be applied across multiple stages of a crop life cycle starting from soil or seed treatment to maturity and ripening stages; through multiple routes depending on crop type, infrastructure availability, soil condition, and agronomic objectives.

- **Fertigation with micro-irrigation:** Fertigation integrates fertiliser delivery with irrigation water through drip or micro-sprinkler systems. This is the most efficient and popular use-case for liquid fertilisers in India. This method allows nutrients to be fed in precise doses synchronized with crop growth stages. Fertigation is most effective for horticulture crops (fruits, vegetables, plantation crops), sugarcane, cotton and high-value crops.

- **Foliar feeding:** In foliar feeding, liquid fertilisers are sprayed directly onto the leaves for rapid nutrient absorption.

  This method is mainly used to correct mid-season nutrient deficiencies (e.g., Zn, B, Ca, Mg), handle stress periods and improve quality parameters like fruit size, colour, Total Soluble Solids (TSS) and shelf life. Foliar sprays are adopted in apple, tomato, grapes, pomegranate, banana, cotton, vegetables and some cereals.

- **Seed treatment and early-stage starter fertilisers:** Some liquid fertilisers-especially those containing phosphorus, micronutrients, or growth promoters-are used as seed coats or early root dips. This helps in improving germination, facilitating early root development and protecting against early nutrient stress.

- **Protected cultivation and hydroponics:** Polyhouses, net houses and hydroponic units rely heavily on liquid nutrient delivery, with carefully controlled electrical conductivity (EC) and pH using water-soluble or true liquid fertilisers.

- **Emerging drone-based liquid application:** Drone based application is gaining traction in India-in view of increasing labor challenges and Government initiatives promoting drone technology. Liquid fertilisers are highly compatible with drone-based application techniques. Studies conducted by various universities have confirmed that drone-based foliar nutrient spray improves physiology, nutrient uptake and yield of various crops.[53]

- **Flood and furrow irrigation:** Liquid fertilisers also find their application through flood and furrow irrigation, especially for large acreage crops like paddy and wheat. Though less prevalent in India, countries like Australia and Mexico use liquid fertilisers through this method (refer exhibit 21)

Exhibit 21: Case Study: The Yaqui valley: Mexico

The Yaqui Valley in Sonora, Mexico, is one of the world's most productive irrigated wheat regions. Yield in the Valley increased about 250% over the 60 years 1960–2019 (harvest years), from 2 to 7 MT/Ha on account of several agronomic changes that were brought about in the region. One of the key impact factors was a large increase in Nitrogen use and subsequently Phosphorus, which were applied into the fields through flood and furrow irrigation systems. This led to a wide scale application and significantly improved nutrient uptake and crop productivity. As a result, The Yaqui Valley remains a leading example of how liquid fertiliser application through surface irrigation can drive large-scale productivity gains.

Source: Tony Fischer, Karim Ammar, Ivan Ortiz Monasterio, Marta Monjardino, Ravi Singh, Nele Verhulst, Sixty years of irrigated wheat yield increase in the Yaqui Valley of Mexico: Past drivers, prospects and sustainability

3.2.3 Advantages of Liquid Fertilisers

Exhibit 22: Advantages of liquid fertilisers

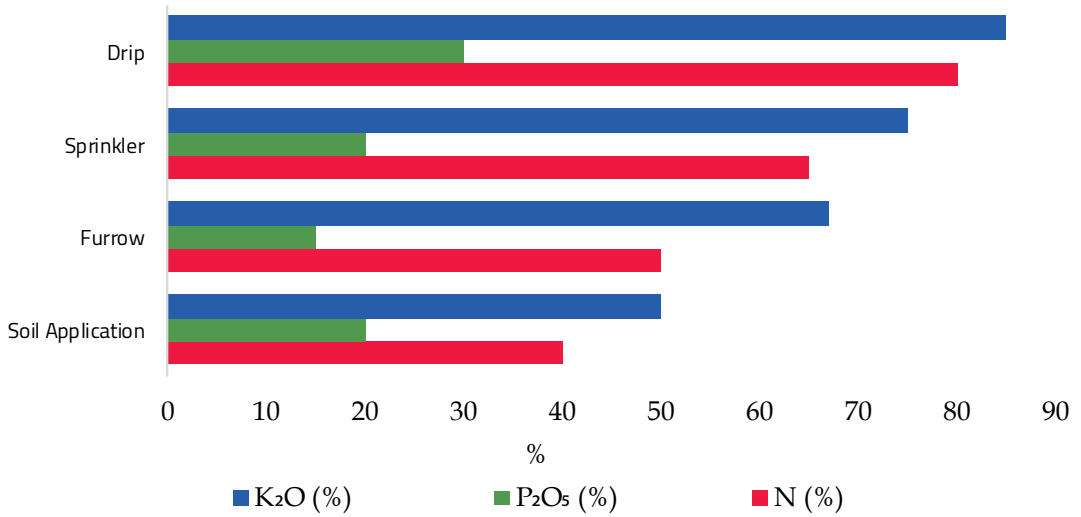


[53] Ramesh, T. ., Dayana, K. ., Rathika, S. ., & Pazhanivelan, S. . (2024). drone-based foliar nutrient spray improves physiology, nutrient uptake and yield of greengram (vigna radiata). the indian journal of agricultural sciences, 94(12), 1381–1384.

Enhanced nutrient use efficiency

Liquid fertilisers enable enhanced nutrient use efficiency as they allow nutrients to be immediately accessible for plant uptake, due to their dissolved form. Application of liquid fertilisers via fertigation delivers nutrients directly to the root zone, in line with crop demand, sharply reducing losses from leaching and volatilization. The absorption rates of nutrients are highest in drip irrigation (refer exhibit 23).

Exhibit 23: Nutrient Uptake Efficiency by Irrigation Method (% average absorption of nutrients)



Source: Tamil Nadu Agricultural University, Jayakumar et al 2014

Yield and quality improvement

Due to their rapid availability and absorption, liquid fertilisers provide quicker crop response compared to granular fertilisers. This is particularly beneficial during critical crop growth stages where timely and balanced nutrient availability directly influences yield and quality. The All India Coordinated Research project (AICRP) on Irrigation Water Management reported a 26–45% increase in crop yield due to drip fertigation. Water productivity in crops due to fertigation ranged from 30.2 to 103.2 kg/ha.mm.[54]

Uniform nutrient distribution and precision

Liquid fertilisers ensure that every drop applied across the field contains the same nutrient concentration, leading to consistent plant growth and eliminating nutrient deficiencies or excesses in specific areas. Moreover, liquid fertilisers are compatible with precision agriculture tools such as soil sensors, fertigation controllers, drones, allowing micro level nutrition management.

Customized nutritional solutions

Liquid fertilisers allow for tailor-made nutrient formulations, including combinations of macronutrients, micronutrients, and specialty inputs, enabling crop-specific and stage-specific nutrient delivery and supporting rapid correction of nutrient deficiencies.

[54] Mohanty, S. & Sandal, S & Rautaray, Sachin & Sarangi, Arjamadutta. (2025). Indian Farming Drip fertigation for Enhancing crop and water productivity. 75. 17-20

Operational convenience

Ready-to-apply liquid fertilisers are easy to use, safe to handle and reduce labor on manual mixing.

Environmental and sustainability alignment

Liquid fertilisers contribute to sustainability by minimizing nutrient losses, runoffs, and soil accumulation of excess nutrients. Their efficient absorption reduces the risk of groundwater contamination and nutrient imbalance. Additionally, precise delivery reduces over-application, contributing to more sustainable soil and ecosystem management.

3.2.4 Market Dynamics

The liquid fertilisers market in India remains at an early but structurally promising stage, supported by increasing adoption of precision agriculture and water-efficient nutrient delivery systems. Industry estimates suggest that liquid fertiliser market in India is valued at approximately USD 40 Mn (FY2025),[55] and has been estimated to be growing at 13-15% CAGR between FY20-FY25. The growth momentum is expected to sustain close to 15% in the medium term, taking the market to USD 80 Mn by 2030.[56]

The key demand hotspots for liquid fertilisers in India are:

- **States with high micro-irrigation penetration:** Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, and parts of Rajasthan.[57]
- **Horticulture belts:** Apples in Himachal Pradesh, Grapes and Pomegranate in Maharashtra, Banana in Tamil Nadu/Gujarat, Vegetables in Karnataka/Andhra Pradesh.
- **High-value cash crops:** Cotton, sugarcane, chillies, potato, onion, and seed production clusters.
- **Emerging drone-spray geographies:** Karnataka, Andhra Pradesh, Madhya Pradesh and parts of Uttar Pradesh.

3.2.5 Evidence of impact

- Precision Farming Development Centre (PFDC) fertigation findings (multi-crop, multi-location): PFDC and associated research under Pradhan Mantri Kisan Sinchai Yojana (PMKSY) report that fertigation saves fertiliser and water ranging from 40-60%.[58]
- Banana yield increase and water saving through drip fertigation-Field experiments conducted on clay loam soil in western Maharashtra for Banana crop put forth encouraging results for fertigation. The study reported beneficial effects of drip fertigation on yield increase-to the tune of 24-46% and 45.3% on water saving.[59]

[55] Including liquid micronutrients

[56] Industry Estimates

[57] Per Drop More Crop (PDMC) 2024 guidelines, MoA&FW

[58] https://pmksy.gov.in/MicroIrrigation/Archive/PFDCs_Research_Findings_on_Fertigation.pdf#:

[59] Pawar, D., & Dingre, S. (2013). Influence of fertigation scheduling through drip on growth and yield of banana in western Maharashtra. Indian Journal of Horticulture, 70(2), 200–205

3.3 Biostimulants

3.3.1 Introduction

As defined in the Fertiliser Control Order, Biostimulants comprise of a substance or microorganism, or a combination of both, that, when applied to plants, seeds, or the rhizosphere, stimulates physiological processes in plants to enhance nutrient uptake, growth, yield, nutritional efficiency, crop quality, and stress tolerance.[60]

As yield gains from conventional fertilisers moderate and climate stress intensifies, it is increasingly being recognised that productivity is no longer driven by nutrients alone, but by how effectively plants convert nutrients into biomass, yield, and quality. Biostimulants operate precisely at this interface—enhancing plant physiological efficiency rather than merely supplying nutrients. Biostimulants work by enhancing a plant's natural physiological processes and improving nutrient uptake, stress tolerance and overall productivity. Effectively, biostimulants do not replace fertilisers, instead, they amplify the effectiveness of applied nutrients, making them a powerful complement.

Derived from a variety of sources, including plant extracts, microbial inoculants, protein hydrolysates, and organic acids, biostimulants play a pivotal role in supporting soil health and improving crop performance under diverse conditions.

Biostimulants approved under Indian regulations fall into four key categories, each with unique functional properties and benefits:

- **Extracts:** Derived from natural sources such as seaweed, bioactive plant compounds, polyphenols, and chitosan, these extracts are known to enhance plant metabolism and stress tolerance.
- **Acids:** These are natural compounds, primarily Humic & Fulvic Acids (improving soil/nutrients) and Amino Acids & Protein Hydrolysates (boosting plant metabolism/stress relief), that stimulate plant growth, improve nutrient efficiency, and increase stress tolerance (drought, heat). These compounds improve soil structure, nutrient availability, root development and improve overall plant health.
- **Microbial Inoculants:** These are beneficial bacteria and fungi, that enrich the soil microbiome, form symbiotic relationships, fix atmospheric nitrogen, solubilize phosphorus, produce growth hormones, and help plants absorb water and nutrients.
- **Other Bioactive Compounds:** These include protein hydrolysates, enzyme extracts, inorganic salts, and anti-transpirants, which aid in stress mitigation and physiological balance.

The list of biostimulants approved in India is provided in Annexure 1.

As biostimulants gain prominence as a key component of sustainable and climate-resilient agriculture, leading markets have adopted distinct approaches to product registration, claim validation and other aspects of the industry. Exhibit 24 compares India's landscape against the markets of USA, EU and Brazil.

[60] As per Fertiliser Control Order. Important to note that biostimulants do not include pesticides or plant growth regulators, which are regulated under separate laws.

Exhibit 24: A comparison of various aspects of Biostimulants industry in India vis-à-vis other key countries/ regions

Aspect	Brazil	European Union (EU)	United States (USA)	India
Legal Framework	Unified Bio-inputs Law (2024)	Fertilising Products Regulation 2019/1009	Fragmented (EPA and state level)	FCO Schedule VI (2021)
Registration Process	Centralized	Conformity Assessment/ Marking (CE) + Component Material Categories (CMC) system*	State/EPA based on claims	Centralized to notify products followed by state level permissions
Registration Requirements	Bioassay only	Bio efficacy based, Residue, Toxicity	3 Bio efficacy trials, Residue, Toxicity, Crop groupings	3 Bio-efficacy, 3 agroclimatic, Residue, Toxicity
Definition Scope	Broadly Includes microbials, peptides, natural inputs	PFC6 + CMC PFC 6 represents the Product Function Category for Plant Biostimulants	No federal definition; claim dependent	Narrow: Only notified ingredients accepted
Innovation Support	Simplified for similar products; encourages on-farm use	Flexible category system CMC enables innovation	Limited by ambiguity and cost	Long trial and approval process
Claim Handling	Multi-use claims, data supported	Scientific validation mandatory for claims	Claims define regulation path; varies	Scientific validation mandatory for claims
Small Producer Access	On-farm, family-scale production exempted	Focused on commercial manufacturing	High cost is a barrier for small firms	High cost is a barrier for small firms
Effective from	2024	2022	NA	2021
Products approved	1500 products		40+	100+ products

*CE (Conformity Assessment/Marking): By affixing the CE mark, the manufacturer certifies that the product complies with all EU health, safety, and environmental protection requirements.

CMC (Component Material Categories): This defines the permitted raw materials and their safety requirements. A CE-marked biostimulant must be composed of one or more materials belonging to specific CMCs, ensuring that the ingredients are safe, traceable, and sustainably sourced.

Source: FICCI Taskforce on Innovative Crop Nutrition

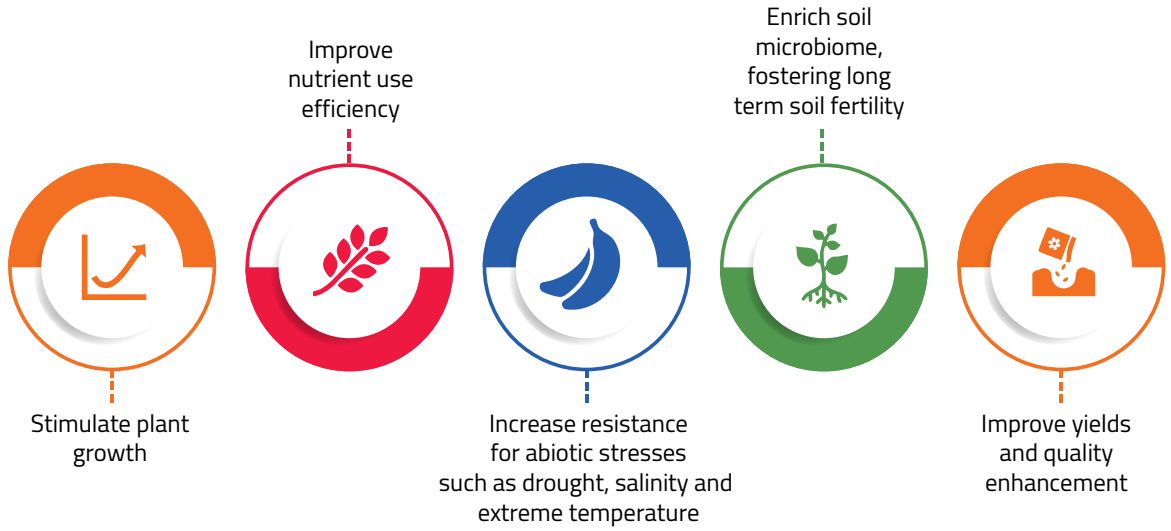
3.3.2 Use & Application

Bio stimulants are versatile in both form and application, and their use depends on product category, crop type, crop growth stage, and the objective of use (e.g., yield improvement, stress mitigation, improved root growth or quality attributes). Common application methods include:

- **Foliar sprays:** This method provides rapid delivery for corrective effects, stress relief, or flowering/fruit-setting support (especially seaweed extracts, protein hydrolysates). This is the most prevalent application method contributing nearly 80% to the biostimulants market.[61]
- **Soil/root-zone application:** Humic/fulvic acids, many microbial bio stimulants, and liquid seaweed products are applied via soil drench or during transplanting to stimulate root growth and rhizosphere activity. Drip injection i.e. integration with irrigation (especially in high-value horticulture and protected cultivation) for controlled, stage-wise delivery is also being practiced. Nearly 15% of the biostimulants market is contributed by soil/root zone application, and its share is expected to increase steadily reaching over 20% by 2030.[62]
- **Seed treatments & seed priming:** This method involves small-dose application for germination vigour, seedling establishment and early-root development (protein hydrolysates, certain microbes).
- **Coatings and granular blends:** Some biostimulants are formulated for co-application with fertilisers or seed coatings to give combined nutrient and bio stimulant effects.

3.3.3 Advantages of biostimulants

Exhibit 25: Advantages of biostimulants



Stimulate plant growth

Biostimulants such as seaweed extracts, humic substances and plant extracts supply hormones and signal molecules that boost root growth, leaf expansion and early vigour, leading to faster canopy closure and stronger seedlings.

[61] Industry estimates

[62] Industry estimates

Improve nutrient use efficiency

Biostimulant applications enable plants to explore a larger volume of soil and have a greater absorption capacity by inducing an increase in root biomass, enabling plants to take up applied NPK and micronutrients more effectively.

Increase resistance for abiotic stresses such as drought, salinity and extreme temperature

Under heat, drought or salinity stress, biostimulants improve photosynthetic efficiency and osmotic balance, reducing flower drop and fruit abortion.

Biostimulants can also induce protection against low temperatures, by the accumulation of cryoprotective substances and/or the activation of membrane repair systems.

Enrich soil microbiome, fostering long term soil fertility

Microbial biostimulants such as Plant Growth-Promoting Rhizobacteria (PGPR), mycorrhizae colonize the rhizosphere, increase beneficial microbial biomass, and enhance nutrient cycling (N fixation, P solubilization).

Improve yields and quality enhancement

- From an outcome perspective, biostimulants deliver moderate but highly consistent gains, especially under stress conditions. Importantly, yield gains are often additive when biostimulants are combined with other innovative fertilisers like liquid fertilisers and micronutrients.
- Biostimulants significantly impact plant growth and development, micro and macronutrient uptake, and translocation in several crops, ultimately leading to increased biomass production and yield. A Meta-Analysis of Bio stimulant Yield Effectiveness in Field Trials put forth that add-on yield benefit among all biostimulant categories on an average was 17.9%.[63]
- Beyond quantity, bio stimulants often raise quality metrics — higher total soluble solids, better fruit firmness, improved nutrient content. Studies conducted on effect of biostimulant Application on Seed Yield and Seed Quality in Rice-conducted in Tamil Nadu showed that rice seedlings treated with biostimulants registered higher values for growth parameters and yield parameters.[64]

3.3.4 Market Dynamics

The Indian biostimulants market is estimated to be valued at about USD 400 million (FY2025), growing at 14–16% CAGR (FY20-FY25). While growth moderated during FY26 due to regulatory changes and compliance requirements, the market is projected to regain momentum. The segment is expected to grow faster over the medium term at an expected growth rate of over 18-20% annually and touch the USD 1 Bn mark by 2030.[65] The biostimulants market is dominated by MSMEs, many of whom are startups.

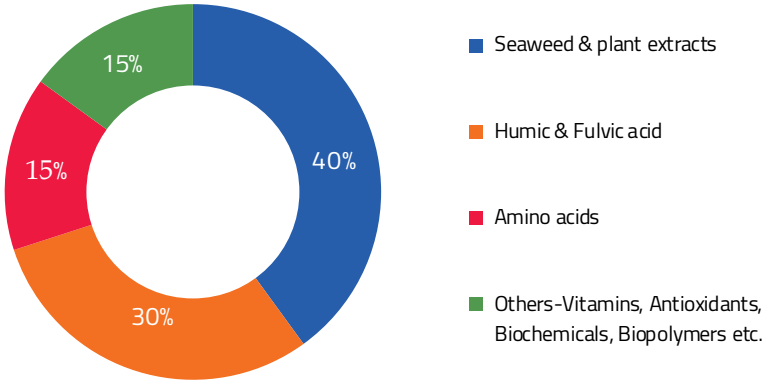
Within the biostimulants segment, seaweed-based and humic/fulvic acid-based products continue to dominate the market with an estimated 70% share, primarily due to farmer familiarity, historical usage and proven efficacy. Microbial inoculants and peptide-based innovations are also gaining momentum, particularly in horticulture and high value segments. Exhibit 26 depicts the bifurcation of biostimulants market in India.

[63] National Center for Biotechnology Information

[64] Elavarasan E., A. Kamaraj, B. Sunil Kumar, P. Satheeshkumar and S. Suganthi (2023). Effect of BioStimulant Application on Seed Yield and Seed Quality in Rice (Oryza sativa L.). Biological Forum – An International Journal,
15(10): 493-497.

[65] Industry discussions/estimates

Exhibit 26: Bifurcation of Biostimulants market in India



Source: Industry discussions

Technological innovations have increasingly become central to improving consistency, efficacy and reliability of biostimulants products through advanced active ingredient extraction and formulation capabilities (refer exhibit 27).

Exhibit 27: Technological innovation in the biostimulants domain

Extraction of Active Ingredients (AIs) from beneficial base compounds is a game-changing area in the field on biostimulants. This is a part of an Innovator's formulation technology and has the potential to make biostimulants highly effective even at very low dosages, while maintaining relatively low per-acre costs for farmers. This has emerged as an area of global innovation within the biostimulants space.

For instance, while multiple seaweed-based extracts are commercially available, the concentration and consistency of active ingredients often vary across batches. This variability leads to inconsistent field performance, reduced product credibility from the farmer's perspective, and lower adoption rates.

In the biostimulants segment, product quality is fundamentally linked to consistency. The ability to isolate, standardize, and extract the precise active ingredients that drive targeted physiological responses in crops is critical to delivering predictable outcomes. The identification and integration of synergistic active ingredients, combined with robust formulation capabilities to ensure stability and extended shelf life, constitute the core drivers of real technological impact in this domain.

Source: Industry Discussions

The key demand hotspots for biostimulants in India are:

- **Field crops:** Common crops with high usage of biostimulants include cotton, sugarcane, maize, wheat, and paddy in heat and drought prone regions. Biostimulants are mainly used during flowering, boll formation, grain filling and stress events. North Indian regions (especially Punjab, Haryana, Uttar Pradesh) leads adoption, driven by intensive wheat and paddy cultivation and fertiliser intensive practices. ~85% of biostimulants are estimated to be used for field crops.[66]

- **Horticulture and high-value crops:** This includes fruits (grapes, bananas, pomegranates, citrus, and mangoes), vegetables (tomatoes, chillies, capsicums, cucumbers) and flowers and plantation crops.

- **Protected cultivation and seed production:** Biostimulants are increasingly embedded into fertigation and foliar schedules in polyhouses and hybrid seed plots, where uniformity and vigour are critical.

3.3.5 Evidence of impact

- A study conducted at JNKVV on paddy variety JR-206 during kharif, 2022-23 revealed that the application of AGMA bio-stimulant granule gave good vegetative growth, more number of ears per plant, good size of ears and highest yield per plant as compared to control.[67]

- A study conducted by Department of Vegetable Science, CCS HAU, Hisar on Impact of biostimulants on growth parameters of capsicum (Capsicum annum L.) highlighted the positive effect of biostimulants on growth and parameters of capsicum. Plant treated with seaweed extract recorded highest plant height (103.22 cm), leaf area (370.63 cm^2) and number of branches per plant (11.63).[68]

- Other similar studies/ trials conducted by ICAR and SAU India have reported positive effects of biostimulants based practices in crops such as maize, vegetables and wheat. For example, multi-season trials and on-station studies documenting improved early vigour, yield components and sometimes overall yield gains under integrated nutrient and biostimulants schedules.



[66] Industry discussions

[67] AK Jha, PS Yadav, Bhumika Lodhi, Debabrata Sarkar, Kuldeep Sharma, Ronak Chhaya. Effect of biostimulants on growth and yield of rice. Int J Res Agron 2024;7(5):282-289

[68] Singh, U. (2025). Impact of bio stimulants on growth parameters of capsicum (Capsicum annum L.). International Journal of Environment, Agriculture and Biotechnology

3.4 Water Soluble Fertilisers & Advanced Macro Nutrient Solutions

3.4.1 Introduction

This section of the report focuses on two key subcategories of innovative crop nutrition: water-soluble fertilisers and advanced macro nutrient solution (Eg. slow-release fertilisers)

Water Soluble Fertilisers (WSFs) are completely (100%) soluble in water and enable complete dissolution and precise delivery of nutrients through fertigation and foliar routes. WSFs are either Complexes or Mixture of Complexes.

Water-Soluble Fertilisers (WSFs) in India is experiencing rapid expansion, driven by the adoption of precision farming, micro-irrigation, and high-value horticulture. Earlier, WSFs had standard NPK grades that were stage-specific grades but not customized for any particular crop. However, at present, with the blending of WSFs becoming mainstream with low entry barriers, there is a strong shift towards WSFs for specific crop stages of a particular crop/ crop group, in line with the nutritional requirements of the crop during that particular crop stage.

Furthermore, in such crop specific, stage specific WSFs, secondary and micro nutrients are being added in 100% water soluble form, providing a clear alternative to bulk/ granular fertilisers and reducing the total number of nutrition products that a farmer needs to buy to ensure holistic and balanced nutrition.

Other advanced macronutrient technologies include:

- Nano fertilisers, Controlled-release Fertilisers (CRFs), Slow-Release Fertilisers (SRFs) and Slow and Controlled Release Formulations (SCRFs)-These products release nutrients gradually over an extended period, providing plants with a consistent supply of essential nutrients.
- Customized fertilisers-These are soil grade granular blends, tailored to meet specific nutrient requirements of different crops & soil conditions.
- Grade specific fertilisers-These are single grade fertilisers supplying multiple nutrients required by crops for additional value & increased nutrient use efficiency.
- Coated fertilisers-These products ensure prolonged supply of nutrients that offer many benefits like sustained nutrient release, reduction in leaching losses etc.

Together, water soluble fertilisers and advanced macronutrient solutions shift crop nutrition from a bulk, input-driven model to an efficiency and outcome driven model, which is increasingly critical in water-stressed, intensively cultivated, and quality-oriented farming systems.

3.4.2 Use & Application

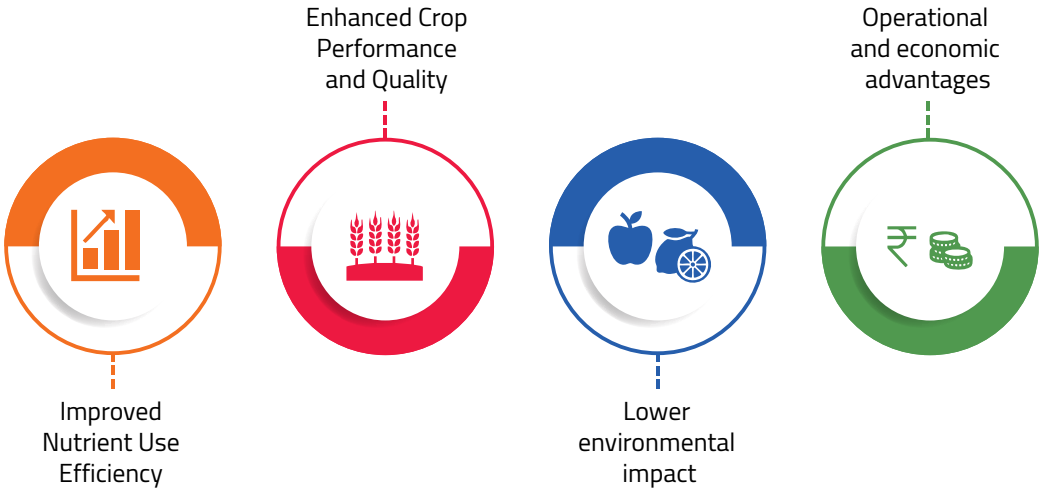
Water-soluble Fertilisers are most commonly used in fertigation systems, integrated with drip and sprinkler irrigation, to deliver nutrients directly to the root zone in dissolved form, enabling frequent, low-dose applications that closely follow the crop's growth stages and nutrient demand. This facilitates effective uptake during sensitive periods such as vegetative growth, flowering and fruiting, and helps avoid inefficiencies associated with soil fixation or delayed dissolution. Because WSFs dissolve completely in water, they provide high bioavailability and uniform nutrient distribution, both critical in horticulture and irrigated cash crops.

Foliar application remains an important complementary pathway for WSFs, particularly where rapid corrective nutrition or micronutrient supplementation is required. Foliar sprays enable plants to absorb nutrients directly through leaf surfaces, bypassing soil constraints such as high pH or low organic matter that reduce nutrient solubility. This is valuable in orchards, high-value vegetables, and pulse crops during critical yield impacting phases.

Advanced macronutrients—such as nano-fertilisers and slow-release formulations—are applied using multiple modes. Slow-release fertilisers are typically applied through soil application at basal or early stages, where polymer or chemical coatings regulate nutrient release over weeks or months in tune with crop needs. Nano-fertilisers, which incorporate nutrients into nanoscale carriers or particles, can be applied either through soil, foliar spray or fertigation, enabling targeted, sustained and efficient nutrient delivery at lower application rates than conventional fertilisers. These approaches are often used in tandem within integrated nutrient management schedules to balance immediate nutrient availability with sustained supply over the crop cycle.

3.4.3 Advantages of Water-Soluble Fertilisers & Advanced Macro Nutrient Solutions

Exhibit 28: Advantages of Water-Soluble Fertilisers & Advanced Macro Nutrient Solutions



Improved Nutrient Use Efficiency

One of the most compelling advantages of WSFs and advanced macronutrient technologies is their ability to enhance nutrient use efficiency (NUE). Conventional fertilisers often suffer from low NUE-typical uptake rates for nitrogen are around 30-40% and for phosphorus even lower-meaning a large fraction of applied nutrients are lost to leaching, volatilisation, and fixation. Technologies such as slow/controlled-release and nano-based fertilisers are explicitly engineered to synchronize nutrient availability with crop demand, reducing waste and ensuring more of the applied nutrient ends up in the plant.

Enhanced crop performance and quality

WSFs ensure that nutrients are available precisely when and where crops need them, leading to improved physiological growth, better root development, enhanced flowering and fruit setting, and more effective grain filling. Advanced macronutrients-nano formulations and controlled-release granules—provide sustained nutrient supply throughout critical growth periods, supporting higher yield stability and improved produce quality, which are essential in high-value horticulture and processing crops.

Lower environmental impact

By reducing nutrient losses, these innovative crop nutrients help mitigate environmental issues associated with traditional fertilisers, including nitrate leaching into groundwater, eutrophication of water bodies, and greenhouse gas emissions from nitrogen volatilisation. Controlled-and slow-release fertilisers release nutrients gradually over time, decreasing peaks in soil nutrient concentration that drive losses, while nano-fertilisers— with nutrient particles <100 nm, deliver higher surface area for absorption, enabling reduced dosages and lowering the environmental footprint.

Operational and economic advantages

Farmers benefit from fewer applications, reduced labour, and improved fertiliser return on investment. WSFs integrated with fertigation systems reduce the need for manual broadcasting, while slow-release products lower the frequency of field operations. Nano-fertilisers, used in very small amounts, reduce input volume and can lower overall nutrient costs over time despite their higher per-unit price.

3.4.4 Market Dynamics

India's water soluble fertiliser market was estimated at around 4.7 lakh MT in FY25, valued at around USD 580 Mn. This market is estimated to be growing at 10-11% CAGR (FY20-FY25). Going forward, the market is expected to grow at similar pace, taking the market size to over ~USD 940 Mn by 2030.[69]

Several drivers shape this market evolution. Micro-irrigation expansion, supported by government programs like Per Drop More Crop, creates demand for soluble nutrients that integrate with fertigation systems, reducing water and nutrient waste. Further, the rise of horticulture, cash crops, protected cultivation, and export-oriented production systems increases demand for quality-enhancing nutrient solutions.

The key demand hotspots for WSF and other advanced macronutrients are:

- Demand for water-soluble fertilisers and advanced macronutrient technologies is particularly strong in regions with high micro-irrigation adoption and crop intensification. States like Maharashtra, Gujarat, and Karnataka exhibit high fertigation use due to extensive drip irrigation in fruits, vegetables, and cotton, creating significant markets for WSFs.
- Horticulture-dominant states such as Tamil Nadu, Andhra Pradesh, and Telangana also show elevated demand, driven by the need for quality and export compliance.
- Traditional field-crop regions are beginning to adopt controlled-release fertilisers as awareness and advisory services grow.

[69] Industry estimates

3.4.5 Evidence of impact

- Recent study on "Emerging trends and perspectives on nano-fertilisers for sustainable agriculture" reported that application of nano fertilisers in key crops such as wheat, potato, maize, and rice have led to significant yield improvements : 20–55% for wheat, 20–35% for potato, 20–40% for maize, and 13–25% for rice. Additionally, grain yield enhancements of 20–55% for wheat, 22–50% for maize, and 30–40% for rice have been observed.[70]

- Two-year field experiment (2020-2021) was carried out to evaluate the effect of nano fertilisers (NF) (phosphorus, zinc, and iron) seed priming and NF foliar spray on the growth, yield, and seed quality characteristics of groundnut var TG-37 A. The results indicated that in both the years, NF seed priming and foliar sprays treatments showed higher seed germination and seedling vigour aiding in early establishment in soil, which manifested by higher plant height, early flowering, higher leaf chlorophyll content, 100-seed weight and shelling percentage. Pod yield per plant was 30.1% and 33.0% higher in 2020 and 2021, respectively, as compared to the control. In both years, the application of nano fertilisers considerably boosted the oil and protein content compared to the control (31.5% and 28.9% for oil, 33.1% and 30.0% for protein).[71]



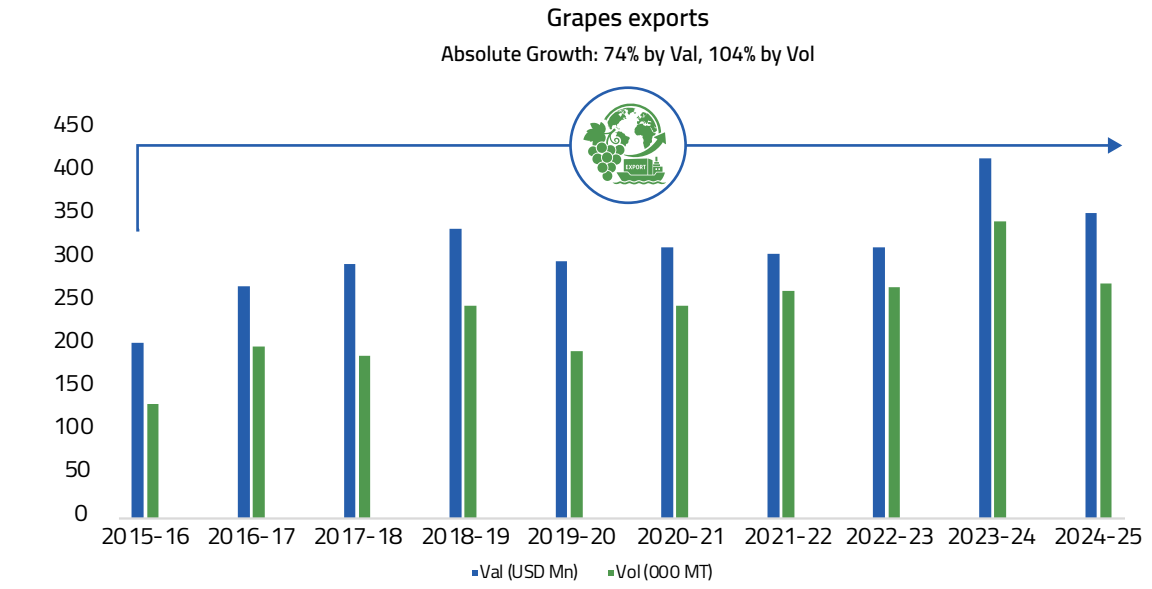
[70] Emerging trends and perspectives on nano-fertilizers for sustainable agriculture

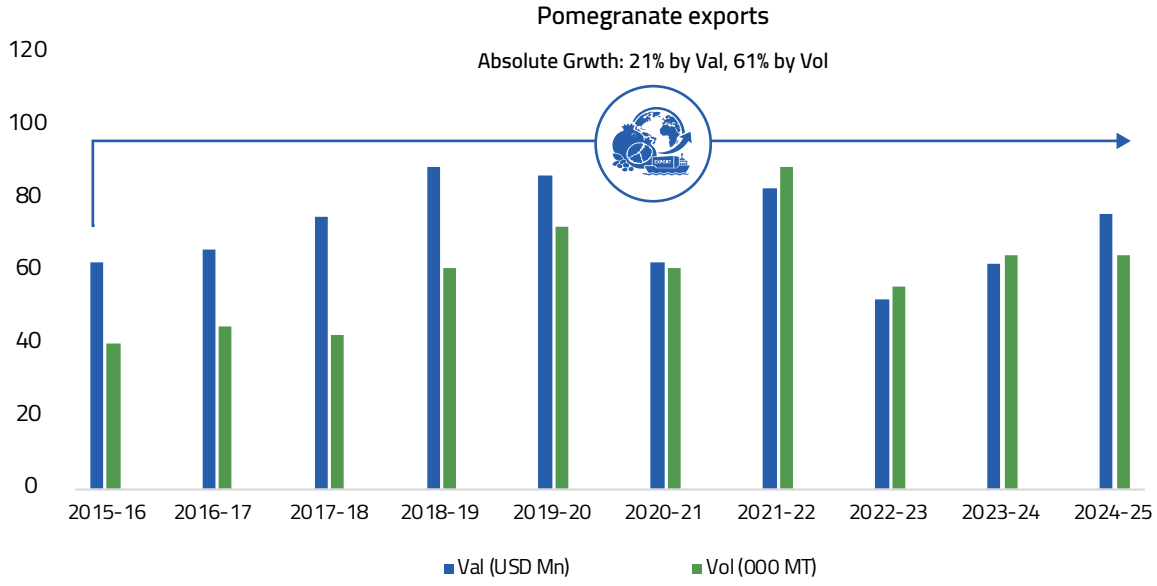
[71] Kona Prabhavathi, Rao Mohana Jagan P., Rao R.G.S., Latha Swarna V., Bharathi Y. (2024). The Influence of Nano-fertilizers Priming on Augmenting Ground-nut (Arachis hypogaea L.) Growth, Yield and Quality . Agricultural Science Digest. 44(4): 645-650. doi: 10.18805/ag.D-5867

Exhibit 29: Case study on the impact of water soluble fertilisers on horticulture sector

Water Soluble Fertilisers (WSFs) were introduced in India way back in the late 1990s. Till 2005, their usage was restricted to Maharashtra, however, by 2011, adoption spread to the states of Gujarat, Madhya Pradesh, erstwhile Andhra Pradesh, Tamil Nadu and Karnataka. From 2011 onwards, many states of North India also started using WSFs.

A landmark initiative in this space was taken in October 2015, when the FCO introduced general guidelines for 100% water soluble mixture of fertilisers. This initiative on the part of Government of India (GoI) led to fast-forward adoption of WSFs in Indian Agriculture. It has been embraced by the private sector and has allowed various organizations to develop and promote a number of crop-specific and stage-specific mixtures in the last decade. This has positively impacted exports of horticulture products like grapes and pomegranates by significantly increasing productivity and quality.





Source: Singh, Gaurav. (2021). Water Soluble Fertilizers in Indian Agriculture. 17(4). 290-296., APEDA

4 Government Regulations and Initiatives for Innovative Crop Nutrition



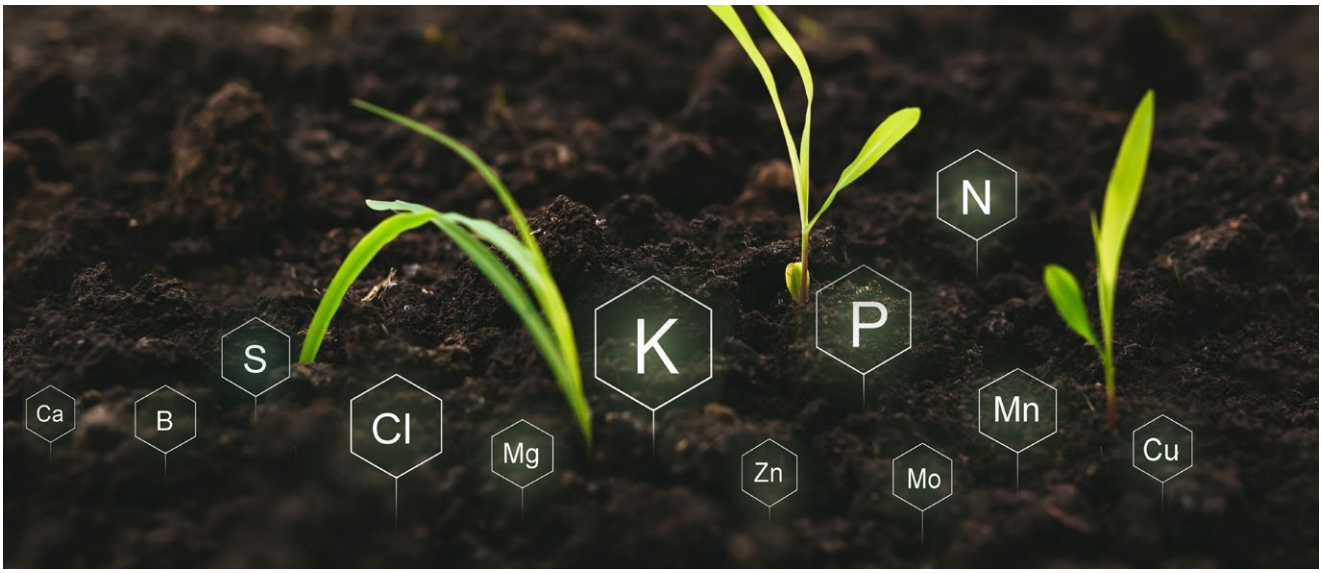
4.1 Key Government Regulations

The crop nutrition sector in India operates under a defined policy and regulatory framework designed to encourage the growth and sustainable application of fertilisers. These regulations also oversee the manufacturing, production, distribution, and pricing of fertilisers in the country. The main instruments guiding this industry are the Fertiliser (Control) Order, the Nutrient-Based Subsidy (NBS) Policy, and the draft Integrated Plant Nutrition Management Bill, 2022.

4.1.1 Fertiliser Control Order

The Fertiliser (Control) Order (FCO), administered by the Department of Agriculture and Cooperation, Government of India, was issued under the Essential Commodities Act, 1955. It defines the substances that qualify as fertilisers for soil application, prescribes product-specific standards, and outlines the methods for sampling and testing. It governs manufacture, import, sale, quality, labelling, and pricing of fertilisers in India.

Part I and subsequent schedules set nutrient and contaminant standards for various fertilisers (e.g., nitrogenous, phosphatic, potassic), biofertilisers, organic manures, and micronutrient formulations. These standards specify minimum nutrient content (like N, P, K, and micronutrients), maximum moisture, pH, biuret, microbial load, and limits on heavy metals. The FCO also strictly prohibits the manufacture /import/sale of any fertiliser which are not of the prescribed standards. State Governments are empowered under FCO to take strict legal action against the offenders. Thus the Controller of fertilisers, central and state agencies, and testing laboratories enforce quality checks, sampling, and analysis. Through its structured and evolving framework, the FCO strives to ensure adequate balanced nutrient application, supports the use of bio and organic fertilisers, and fosters sustainable agriculture while safeguarding farmers' interests and soil health.



4.1.2 Nutrient-Based Subsidy Policy

The Government rolled out the Nutrient Based Subsidy (NBS) Policy on April 1, 2010, succeeding the earlier concession scheme for decontrolled phosphatic and potassic (P & K) fertilisers (extended to SSP from May 1, 2010 and inclusion of NPK 16-16-16 complex fertiliser in 1st July 2010). The policy was introduced to strengthen national food security, enhance agricultural productivity, and promote the balanced use of fertilisers. The program is administered by the Department of Fertilizers, Ministry of Chemicals and Fertilizers.

Under the NBS framework, subsidies are determined based on the nutrient content of fertilisers, primarily NPKS: Nitrogen (N), Phosphorus (P), Potassium (K), and Sulphur (S). This approach not only encourages balanced nutrient application but also empowers farmers to make informed choices that align with the specific needs of their soil and crops. By promoting the use of secondary and micronutrients, the scheme also tries to address the issues of soil degradation and nutrient imbalance that have emerged from years of skewed fertiliser usage.

4.1.3 Integrated Plant Nutrition Management Bill, 2022 (Draft stage)

The draft Integrated Plant Nutrition Management Bill, 2022, seeks to advance the sustainable and balanced use of fertilisers, encompassing bio-fertilisers, bio-stimulants, nano-fertilisers, and organic fertilisers. The bill aims to streamline processes related to fertiliser manufacturing, distribution, and pricing, enhance ease of doing business, and promote research and innovation in high-yielding, climate-smart agricultural systems. The bill is still under consideration.

4.2 Government Initiatives to Promote the Use of Innovative Nutrients

Improving nutrient efficiency has emerged as a central policy imperative as India seeks to raise farm productivity while containing subsidy burdens and mitigating environmental stress. Against this backdrop, the Government of India has increasingly moved beyond volume-centric fertiliser support toward interventions that encourage precision, efficiency and innovation in crop nutrition. Through a combination of tax reforms, soil health diagnostics, extension of micro irrigation system that forms the backbone of many innovative crop nutrition solutions, public policy is actively supporting adoption of innovative nutrient solutions that can deliver higher yields per unit of input, restore soil health and improve farm-level economics. Some of these initiatives are captured in exhibit 30.

Exhibit 30: Key government initiatives to promote the use of innovative nutrients

Soil Health Card

Enables soil test–based nutrient recommendations, directly driving demand for micronutrients, customised fertilisers, liquid nutrients and precision nutrient solutions to address location-specific deficiencies.

PM PRANAM Yojana

Incentivises states to reduce chemical fertiliser consumption, indirectly promoting alternative and innovative nutrients such as biostimulants and efficiency-enhancing formulations.

Paramparagat Krishi Vikas Yojana

Facilitates cluster-based adoption of organic and biological inputs, supporting the use of biofertilisers and bio-stimulants as alternatives to conventional fertilisers.

More Crop Per Drop (Per Drop More Crop) – PMKSY & Micro Irrigation Fund

By expanding micro-irrigation and fertigation, this scheme structurally enables the use of water-soluble fertilisers, liquid nutrients and precision nutrient delivery systems.

GST reduction on fertilisers and select innovative nutrients

Lower GST rates on fertilisers and several nutrient inputs improve affordability and market access for specialty fertilisers, micronutrients and liquid formulations, supporting wider adoption.

Khet Bachao Abhiyan

A month long (June 2026) program to create awareness among farmers about soil testing, balanced nutrient management, natural farming, modern sowing techniques, water conservation, and advanced agricultural practices.

Source: PIB, ICAR,myscheme.gov.in

4.2.1 Soil Health Card

Launched in 2015, the Soil Health Card scheme provides information on the soil's key nutrient status (including 12 parameters such as micronutrient status, NPK, pH, organic carbon, etc.). This enables farmers to make better-informed decisions regarding the quality of their soil and the need for recommended nutrients. It guides farmers toward better nutrient management practices, enabling them to adopt soil improvement measures. Under the program, farmers receive a Soil Health Card every two years. By shifting from blanket usage of fertilisers to need-based nutrient management, the scheme aims to improve crop yield and soil fertility. Since its inception, over 25 crore soil health card have been distributed to farmers across India. This has been made possible through the establishment of more than eight thousand soil testing laboratories.[72]

[72] Press information Bureau 2025, https://www.pib.gov.in/PressNoteDetails.aspx?ModuleId=3&NoteId=155036&reg=3&lang=2

4.2.2 PM PRANAM

Prime Minister's Program for Restoration, Awareness, Nourishment, and Amelioration of Mother Earth (PM-PRANAM) is a central government scheme that promotes the judicious use of chemical fertilisers and encourages balanced nutrient application. It advocates the adoption of sustainable alternatives, including biofertilisers. The scheme operates by providing incentives to state governments that successfully reduce the use of chemical fertilisers, and provide better incentive structure for improved nutrient management.

4.2.3 Paramparagat Krishi Vikas Yojana

Paramparagat Krishi Vikas Yojana (PKVY) is a flagship scheme under the National Mission for Sustainable Agriculture aimed at promoting organic farming through a cluster-based approach. The scheme focuses on building long-term soil fertility, conserving natural resources, and reducing dependency on chemical inputs. Farmers are encouraged to adopt innovative nutrient management practices using organic inputs such as biofertilisers, neem-based formulations, and other eco-friendly products.

4.2.4 Promotion of Micro Irrigation

The Department of Agriculture & Farmers Welfare implemented the Centrally Sponsored Scheme (CSS) of Per Drop More Crop (PDMC) in the Country from the year 2015-16 to 2021-22 as a component of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). From the year 2022-23, the scheme is being implemented under the Rashtriya Krishi Vikas Yojana (RKVY). PDMC scheme focuses on enhancing water use efficiency at farm level through Micro Irrigation, namely, Drip and Sprinkler Irrigation systems.

Further, to facilitate the states in mobilising resources for expanding coverage of micro irrigation, GoI created the Micro Irrigation Fund (MIF) with NABARD with initial corpus of INR 5000 Crore. States can avail loan from MIF for taking up special and innovative projects for expanding coverage of Micro Irrigation and also for incentivising micro irrigation beyond the provisions available under PDMC scheme to encourage farmers. GoI provides interest subvention @3% on the loan availed by the States which is met from PDMC Scheme.[73]

4.2.5 GST Reduction

The Central Government has reduced GST on fertiliser inputs (like ammonia, sulphuric acid, nitric acid) from 18% to 5%. GST on bio-pesticides and several micronutrients has also been reduced from 12% to 5%,[74] making these nutrients more affordable. This reduction aims to encourage farmers to shift from chemical pesticides to alternatives, improving soil health and crop quality.

4.2.6 Khet Bachao Abhiyan

The government launched the nationwide "Khet Bachao Abhiyan" (Save the Farm Campaign) in June 2026, a month-long soil health and farmer awareness movement running across India. Under the campaign, agricultural scientists, experts from agricultural universities, officials of Krishi Vigyan Kendra, agriculture department teams, and public representatives will visit villages across the country to create awareness among farmers. Farmers will be educated about soil testing, balanced nutrient management, natural farming, modern sowing techniques, water conservation, and advanced agricultural practices.

[73] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2003188&reg=48&lang=2

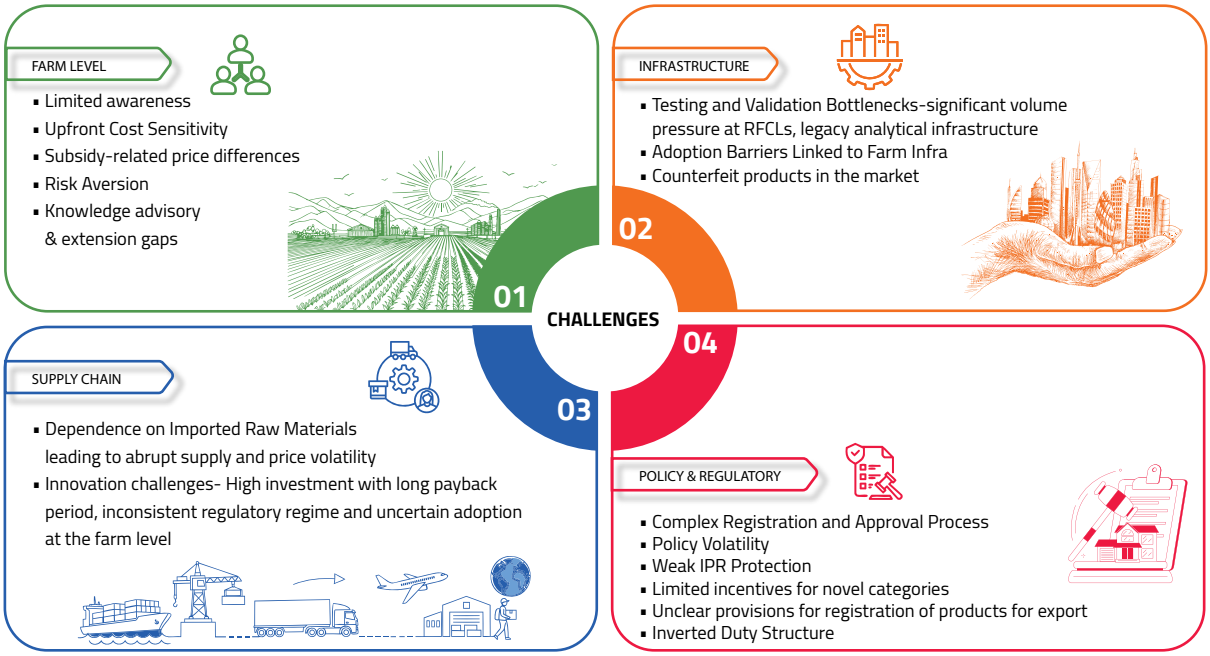
[74] Press Information Bureau 2025, Government of India, https://www.pib.gov.in/FactsheetDetails.aspx?Id=149272&reg=3&lang=2

5 Barriers to Scaling Innovative Crop Nutrition Solutions



Despite the clear agronomic and environmental advantages of next-generation nutrient solutions—their widespread adoption remains constrained. The barriers are multidimensional and span across the supply chain ranging from limited farmer awareness to supply chain constraints, regulatory challenges and inadequate on-ground ecosystem enablers. The key challenges are presented in this section of the report.

Exhibit 31: Key challenges in scaling innovative crop nutrition solutions



Source: Industry discussions

5.1 Farm level

5.1.1 Limited awareness at ground level

Despite growing evidence of yield, quality, and resilience benefits, awareness on innovative crop nutrition solutions remains limited, particularly among smallholder farmers. Such solutions are often perceived as optional or supplementary rather than integral to crop management. This perception is reinforced by entrenched generational practices and peer influence, with decision-making heavily skewed towards past experience and visible short-term yield gains rather than longer-term soil health, nutrient efficiency, and sustainability outcomes.

5.1.2 Upfront cost sensitivity and subsidy-related price differences

Indian farmers have historically relied on visible, short-term yield responses from conventional fertilisers—particularly nitrogenous—reinforced by decades of price support and extension messaging. As a result, fertiliser consumption remains heavily skewed towards urea, which accounts for nearly 60% of total fertiliser use in India,[75] leading to imbalanced nutrient application. In contrast, innovative crop nutrition products are largely sold at market-linked prices, creating an uneven cost–benefit comparison at the farm level and discouraging adoption despite their longer-term productivity and efficiency gains.

5.1.3 Risk aversion and preference for familiar inputs

Innovative crop nutrition products typically deliver benefits through improved nutrient use efficiency, enhanced stress tolerance, better produce quality, and gradual improvements in productivity and soil health, rather than immediate yield spikes. These benefits may be difficult to observe within a single cropping season, particularly in rainfed and variable agro-climatic conditions. With over 86%[76] of Indian farmers classified as small and marginal, risk aversion remains high, and input choices are naturally biased towards familiar products that promise short-term certainty.

5.1.4 Labour and skill constraints in application

Many innovative crop nutrition solutions require more precise and knowledge-intensive application methods—such as fertigation, foliar sprays, or timed interventions—compared to bulk fertilisers. Shortage of skilled farm labour, coupled with limited access to mechanisation and application equipment, act as an additional barrier to adoption at scale.

5.1.5 Knowledge, advisory & extension gaps

The effectiveness of innovative crop nutrition is highly dependent on correct application, crop-specific tailoring, and integration with soil and water management practices. However, India's extension ecosystem remains stretched, with limited last-mile capacity to translate product science into simple, actionable guidance.

While industry players often fill this gap, the coverage is uneven and skewed towards commercially active regions and crops. Public extension systems are still largely oriented toward conventional fertiliser recommendations, with limited capacity to mainstream newer categories into standard agronomic advisories. This creates a knowledge asymmetry, and limits adoption of innovative crop nutrition products at a larger scale.

[75] 69th Fertiliser Statistics 2023-24, The Fertiliser Association of India (FAI)

[76] Press Information Bureau, MoA&FW

5.2 Infrastructure

5.2.1 Testing and validation bottlenecks

- India imports significant quantities of fertilisers, fertiliser intermediates and speciality nutrients to bridge domestic supply gaps. Each imported consignment is required to be sampled and tested as per FCO norms before clearance for sale or distribution and Regional Fertiliser Control Laboratories (RFCLs) function as key institutions for this quality testing. However, the increasing volumes and growing diversity of imported fertiliser products—ranging from conventional nutrients to water-soluble fertilisers, micronutrients and biologicals—have put forth structural challenges in the import clearance and quality assurance process.

- RFCLs face significant volume pressure, especially during peak import seasons ahead of kharif and rabi sowing. While the number of notified laboratories has increased, testing capabilities, capacities and human resources have not expanded at the same pace as import volumes. This results in backlogs, extended turnaround times and delays in consignment clearance.

- The fertiliser import landscape is rapidly diversifying, with increasing imports of speciality and innovative nutrients. While amendments to the FCO have progressively included new categories, testing protocols and analytical standards for many products are still evolving. RFCLs often face challenges in interpreting specifications and validating test methods for novel products. This ambiguity results in inconsistent interpretations across ports and laboratories, creating uncertainty for importers and slowing market entry of innovative products.

- Many laboratories operate with legacy analytical infrastructure, which is adequate for conventional fertilisers but less suited for newer categories (chelated fertilisers, nano fertilisers, biostimulants etc.). Testing such products requires high-end analytical instruments, standard reference materials and skilled manpower. Such infrastructure that is suitably accredited (NABL/SGS-certified labs) and is well equipped for high end testing (e.g. for biosafety and efficacy of innovative products) is at present inadequately available in India.

5.2.2 Adoption barriers linked to farm infrastructure

Adoption of some advanced nutrients like liquid fertilisers, water soluble fertilisers etc. is closely linked with micro-irrigation, protected cultivation, which are still limited to a fraction of India's agricultural land. In the absence of this enabling infrastructure, the performance advantages are not fully realised.

5.2.3 Distribution and storage limitations

Few innovative crop nutrition products (e.g. biofertilisers, biostimulants) are sensitive to heat and humidity. The absence of cold chain infrastructure in rural areas results in degradation in product quality during storage and transportation, leading to reduced efficacy and inconsistency at the farm level.

5.3 Supply Chain

5.3.1 Dependence on imported raw materials

Many innovative nutrients rely on imported inputs. This exposes the supply chain to currency fluctuations, trade restrictions, and shifts in global political and economic conditions, making pricing volatile and planning uncertain for both manufacturers and distributors.

5.3.2 Innovation bottlenecks

The changing agricultural dynamics call for continuous innovation in the crop nutrition segment. However, developing new formulations requires substantial R&D expenditure. With long payback periods, inconsistent regulatory regime weak IPR protection and uncertain adoption at the farm level, industry faces challenges in justifying sustained investments, which limits the pace of innovation.

5.3.3 Counterfeit products in the market

The presence of counterfeit and spurious products in the market continues to remain a major challenge for the innovative crop nutrition industry. Their proliferation not only erodes farmer trust and market integrity but also leads to reactive policy interventions that affect the entire crop nutrition industry.

5.4 Policy & Regulatory

5.4.1 Complex registration and approval process

- India's regulatory framework for fertilisers, governed by the Fertiliser Control Order (FCO), is well established but largely designed for conventional nutrient products. As a result, innovation-led solutions—such as high nutrient use efficiency formulations, biostimulants, biologicals, and nano-scale formulations—are required to navigate approval pathways that are not fully aligned with their scientific and commercial characteristics. The processes for approval, notification, and inclusion of new products are rigorous, time-intensive, and administratively complex and lack transparency in communication. A new fertiliser product registration in India takes around 800 days as compared to 90 days in USA, 30 days in the European Union and 15 days in Vietnam (refer exhibit 32).[77]

Exhibit 32: A comparison of fertiliser product registration process in various countries

Country	Number of Days	Efficacy Trials	Cost to Register (% of income per capita)	Registration Process in Brief
Austria, France, Germany, UK (EU Countries)	0-30	No	0	Based on fertiliser product categories and raw material, manufacturers to comply with different conformity assessment procedures. Fertiliser manufacturers are required to prepare technical materials and apply for conformity assessment to a Notified Body accredited by the EU. Once the Notified Body determines that the fertilizing product meets compliance requirements, it issues a certification/ approval.

[77] Enabling the Business of Agriculture, World Bank Group, Industry discussions

Country	Number of Days	Efficacy Trials	Cost to Register (% of income per capita)	Registration Process in Brief
USA	90	No	0.2	Product should meet the minimum specifications set in the Act Manufacturer to apply to each State – normally takes 2 weeks for registration Label Claims are reviewed-post which registration is granted for sale/distribution
Japan	30	No	1.2%	Label Claim
Vietnam	15	No	4.7%	Automatic approval based on minimum nutrient content-label claim
Malaysia	NA	No	NA	No registration required
India	804	Yes	14%	Multilocational Trails for minimum one season Approval/Notification/State licences

Source: Enabling the Business of Agriculture, World Bank Group, Industry discussions

- For several innovative crop nutrition categories, the registration framework entails extensive documentation, multi-location field trials, and validation across diverse agroclimatic zones. For example, biostimulant products are required to demonstrate bio-efficacy through trials conducted across three universities, one season, and three agroclimatic zones, in addition to submitting detailed data on chemistry, shelf life, compatibility, and residue analysis from NABL-accredited laboratories. It takes around 1-1.5 years to generate this data and costs around INR 30 lakhs per product. While scientifically robust, these requirements significantly increase the cost, duration, and resource intensity of market entry, particularly for MSMEs and innovation-driven startups.
- The decentralized approval architecture under the FCO, characterized by overlapping central and state-level processes, often results in prolonged timelines. Industry feedback suggests that approval cycles can extend from 12 to 18 months before a product is eligible for commercialization, leading to high compliance costs, delayed market entry, and extended time-to-revenue.
- Absence of strict quality benchmarks and monitoring mechanisms leads to market flooding with substandard or inconsistent products. this gap undermines farmer confidence and puts to disadvantage the compliant manufacturers.
- For innovative crop nutrition, targeting reduced dosages of fertilisers, microbial or enzymatic activity, reduced GHG emission, or other sustainability targets, including lower consumption of energy, are not part of the regulatory framework.

- There is no clear communication or documentation of minutes of meetings that can provide transparency to industry stakeholders.

5.4.2 Policy volatility

Policy volatility at the state level poses a major challenge for the non-subsidized fertiliser segment, as states exercise significant control over licensing, inspections, product approvals, and distribution mechanisms. Frequent regulatory actions such as sudden license suspensions and product sales restrictions create an uneven and unpredictable operating environment. Differences in interpretation and enforcement of national regulations across states further increase compliance complexity and delay product rollout, particularly for specialty fertilisers.

Biostimulants is one the categories that have been impacted severely by policy volatility. While amendments to the FCO brought biostimulants within a notified regulatory framework, the transition has been marked by frequent notifications, changing guidelines and evolving compliance requirements, including new data submission formats, testing protocols and labelling norms. For industry players, especially MSMEs and innovation-driven startups, this has resulted in repeated reformulation or re-registration costs, delays in product launches and uncertainty around the validity of existing approvals.

5.4.3 Weak Intellectual Property (IP) protection

Despite the scientific differentiation embedded in many innovative crop nutrition products, intellectual property protection in the sector remains weak in practice. Proprietary formulations, once registered, are relatively easy to replicate due to limited enforcement of protection norms and challenges in proving formulation-level infringement. This significantly reduces the ability of innovators to appropriate returns on R&D investments. As a result, early movers are often discouraged from making sustained investments in advanced formulation science, field validation, and product improvement, ultimately constraining innovation intensity and long-term sectoral growth.

Lack of swift enforcement, even at established High Courts, repeated adjournments in the process of litigation, place an additional burden on innovator companies.

5.4.4 Limited incentives for novel categories

- Current policy frameworks continue to be skewed toward conventional fertilisers, particularly NPK-based products. Subsidy structures and support mechanisms for micronutrients such as zinc and boron have remained largely unchanged over extended periods, offering limited stimulus for innovation or value addition. While select products, such as nano urea and nano DAP have received formal recognition, the broader universe of advanced nutrients, including other nano formulations, slow and controlled release fertilisers, and efficiency enhancing blends, remains outside a clearly defined incentive or regulatory pathway.

- There are also no incentives for products which increase carbon sequestration, consume lower energy compared to standard bulk fertilisers with higher cost benefit ratios, and reduce GHG emissions from agriculture (on farm use), which should be an imperative for mitigating climate change.

5.4.5 Lack of provision for registration of products for exports

At present, there are no provisions for export-oriented registration of innovative crop nutrition products. Consequently, the country suffers a direct and measurable loss in earnings. In the absence of defined pathways for export approvals, Indian manufacturers face constraints in accessing international markets, even where products

meet global quality and performance standards. This leaves a significant share of global demand unaddressed, curtailing revenue growth opportunities for domestic players and weakening India's competitive position in the rapidly evolving global nutrient innovation landscape. Clear export facilitation mechanisms could enable Indian firms to leverage their cost, formulation, and manufacturing strengths to scale internationally.

5.4.6 Inverted duty structure

The classification of micronutrients in the 5% GST slab under the Next Generation GST Reforms[78] announced by the government is a positive step towards supporting the industry and advancing the Make in India initiative. However, several key raw materials and intermediates used in micronutrient manufacturing continue to attract a higher GST rate of 18%, resulting in an inverted duty structure. This distortion arises partly because only a limited number of finished products are permitted under the Manufacturer Registration Certificate (MRC) as per the Fertiliser Control Order (FCO), while other products are required to be sold under the Dealer Registration Certificate (DRC), which attracts a higher tax rate. Additionally, many raw materials and inputs used in micronutrient formulations fall under the broader chemical category and are taxed at higher rates. As a result, manufacturers face a situation where input taxes exceed the tax on final product. This not only increases working capital pressure by accumulating excess input tax credit but also reduces cost competitiveness for domestic producers, especially MSMEs.



[78] Press Information Bureau, https://www.pib.gov.in/FactsheetDetails.aspx?Id=150302&reg=3&lang=2

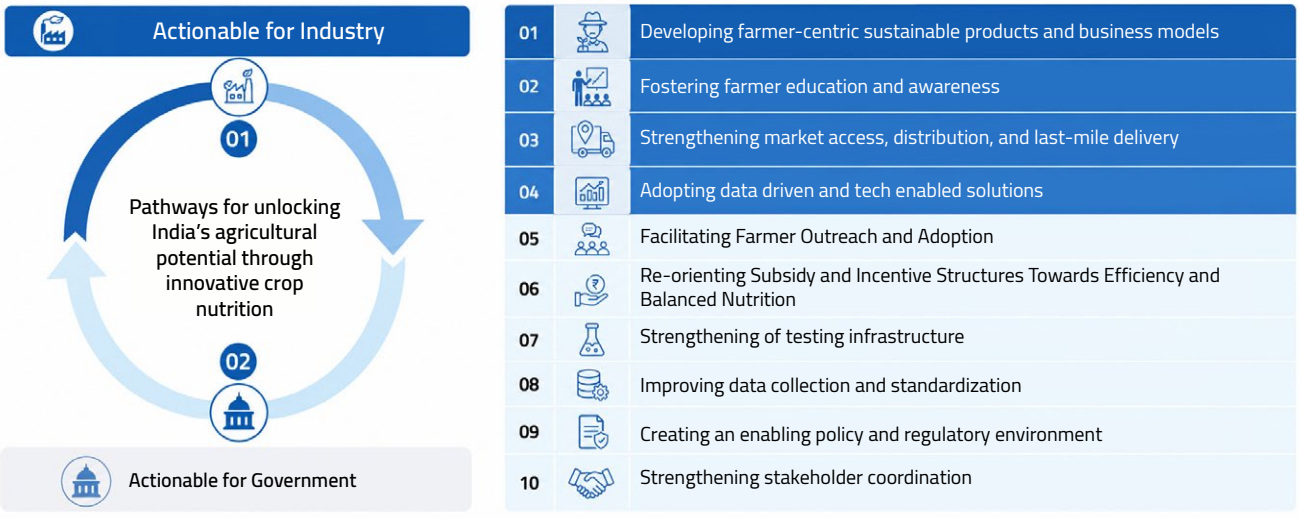
6

Pathways for Unlocking India's Agricultural Potential through Innovative Crop Nutrition



Unlocking the full potential of innovative crop nutrition requires a coordinated, ecosystem-wide approach. Government action is critical to create predictable, science-based regulation, rationalise incentives, strengthen public testing and extension infrastructure, and de-risk early adoption. The private sector needs to drive product innovation, field validation and farmer engagement. Together, public–private collaboration can create an enabling ecosystem that accelerates innovation, scales adoption, and delivers measurable outcomes for farmers and the environment. This chapter outlines a set of actionable recommendations for the industry and the government (refer exhibit 33). Together, these measures aim to accelerate adoption, improve nutrient efficiency, reduce fiscal and environmental costs, and position crop nutrition as a cornerstone of India's next phase of agricultural transformation.

Exhibit 33: Recommendations for the Industry and the Government



Source: Industry Discussions

6.1 Actionable for Industry

6.1.1 Developing farmer-centric sustainable products and business models

- Innovate products and nutrition systems that are outcome-oriented and deliver consistent productivity gains, income improvement, and long-term soil health. This requires anchoring R&D to regional soil deficiencies, agro-climatic conditions, and dominant cropping patterns, rather than uniform national formulations.
- Develop integrated and multifunctional nutrient products that combine macro, secondary and micronutrients, along with efficiency enhancers. This can significantly simplify nutrient management for farmers by reducing the number of applications and operational decisions required.
- Sustainability needs to be embedded into product design through improved nutrient use efficiency, reduced losses, and enhanced soil biological activity, positioning sustainability not as a regulatory obligation but as productivity and resilience enabler.
- Affordability and risk perception remain key constraints for many farmers. Therefore, innovation in business models alongside products is also important. Trial-based offerings and smaller pack sizes can lower entry barriers and encourage experimentation. Partnerships with financial institutions, insurers, and agri-fintech players can enable credit-linked or outcome-based financing models that reduce upfront risk for farmers.

6.1.2 Fostering farmer education and awareness

- Farmer education and trust are critical for large scale adoption of innovative crop nutrition. Industry efforts must move beyond awareness campaigns to structured, multi-season capability-building programmes.

  Large-scale, field-based demonstrations that clearly link innovative nutrition to yield improvement, cost efficiency, and income gains are critical to building trust. In the longer term, evidence generation must extend beyond yield to include nutrient use efficiency, soil health indicators, and sustainability parameters.

  Also, translating this evidence into simple, farmer-friendly narratives using local language and regional examples is critical to strengthening trust and accelerating adoption.
- Collaboration of industry with collective institutions such as FPOs and cooperatives can play a pivotal role in accelerating adoption by enabling peer learning, shared risk, and collective action.

6.1.3 Strengthening market access, distribution and last-mile delivery

- Even where awareness and demand exist, adoption is often constrained by weak last-mile delivery systems. Strengthening distribution requires upgrading dealers and distributors from transactional intermediaries to trusted agronomic advisors, equipped with advisory tools and incentives aligned to quality outcomes rather than sales volume alone.
- Ensure timely product availability during critical crop stages and reduce stock-outs in high-potential regions.
- Bundle innovative nutrition products with services such as soil testing, advisory and application support. This can significantly improve correct usage, outcomes and farmer satisfaction.

6.1.4 Adopting data driven and tech enabled solutions

- Data driven precision will be central to improving nutrient use efficiency and scaling adoption, but its success depends on usability and relevance at the farm level. Integrating soil health data with crop stage, weather patterns and local agronomic practices enables delivery of timely and context-specific nutrient recommendations. However, digital tools must translate complex analytics into simple, actionable guidance to avoid overwhelming farmers.

- Integrated demonstration ecosystems, developed in partnership with agritech firms, research institutions and state agencies can serve as centers that showcase the tangible benefits of precision nutrition while simultaneously building farmer capacity.

- Mapping of soil data and available crop nutrition products-Integrating soil intelligence into agronomic decision-making is a foundational pillar of precision nutrition. Thus, there is a critical need to systematically map soil conditions to existing nutrient solutions. Such alignment is essential to improving nutrient use efficiency and enhancing farm level return on investment. Despite the availability of extensive soil health datasets, their potential remains largely underutilized in guiding product development, positioning, and deployment across the crop nutrition ecosystem. The industry should leverage the existing national datasets (on soil health, crop production etc.) to map nutrient deficiencies and soil characteristics against available crop nutrition products. This data-driven approach can enable companies to identify gaps, develop targeted solutions, optimize product portfolios, strengthen market outreach, and improve the effectiveness of nutrient interventions at the farm level.

6.2 Actionable for Government

6.2.1 Facilitating Farmer Outreach and Adoption

- A well-informed and efficient extension system is central to driving adoption of innovative crop nutrition. Thus, prioritising capacity building of extension officers to ensure they are equipped with up-to-date knowledge on advanced nutrients, precision application and soil health management remains very critical.

- Leveraging digital extension platforms alongside traditional outreach can significantly expand reach, while ensuring advisory remains context-specific and farmer-friendly. Stronger extension capacity also helps counter misinformation and misuse of innovative products.

- Conducting awareness campaigns to help farmers understand the long-term benefits of adoption of balanced nutrition with innovative crop nutrients, including higher yields, lower input costs, and improved soil sustainability is important.

- Public schemes and missions also represent powerful vehicles for mainstreaming innovative crop nutrition. Integrating advanced nutrient solutions into programmes focused on soil health, productivity enhancement, and climate resilience can accelerate adoption at scale. Government extension programmes may actively promote the role of innovative nutrients in addressing region-specific deficiencies and yield gaps.

- The Government can also play an important role in evidence generation and creating credibility by supporting multi-location, multi-season trials through public research institutions and state agricultural universities. Publishing trial results in farmer-friendly formats and regional languages can significantly improve transparency and trust.

- IARI and other crop research institutions need to consider evaluating the revision of Recommended Dose of Fertilisers (RDFs) based on evidence from trials. While research has been undertaken at various institutions on reducing RDF through the use of alternative high nutrient use efficiency (NUE) fertilisers that support balanced nutrition, these findings have not yet been systematically translated into updated fertiliser recommendations by agricultural research institutions for dissemination through KVKs and state agricultural colleges.

6.2.2 Re-orienting Subsidy and Incentive Structures Towards Efficiency and Balanced Nutrition

- Provision of grants (through capex grants, PLI type schemes), tax incentives, or dedicated funds for R&D focused on improving nutrient use efficiency can fast track innovation and commercialization in the innovative nutrient space. Such measures can help reduce fiscal burden, import dependence, encourage entrepreneurship, and promote "Make in India" and "Atmanirbharta".

- Incentives for innovation in technology towards bringing in efficiencies in the supply chain may be considered.

- Free market pricing for fortified fertilisers-The existing subsidy support for zinc and boron fortified fertilisers under the NBS framework has not kept pace with rising fortification and manufacturing costs. Consequently, the economic incentive for producing fortified fertilisers has weakened, resulting in limited availability of these products despite the growing prevalence of micronutrient deficiencies in Indian soils. Free market pricing of fortified fertilisers may therefore be considered. Such an approach would enable manufacturers to recover the additional cost of fortification and improve product availability. On the other hand, farmers will be able to access a wider range of fortified products and can make informed choices based on crop requirements and expected productivity gains.

6.2.3 Strengthening of testing infrastructure

- Expanding and modernising testing capacity is a foundational priority. Accreditation of a wider network of private and public laboratories under NABL (National Accreditation Board for Testing and Calibration Laboratories) for fertiliser and specialty nutrient testing can significantly reduce turnaround time and regional bottlenecks. Enabling NABL-accredited laboratories to conduct testing currently concentrated within Regional Fertiliser Control Laboratories (RFCLs) would decentralise capacity, ease pressure on government labs and materially improve the efficiency of quality monitoring. Faster testing cycles are particularly critical for innovative and time-sensitive products, where delays can disrupt seasonal application windows.

- Within the existing testing ecosystem, capacities need to be developed through infrastructure upgradation as well as skill building for new analytical methods to accommodate emerging and novel input products, including biologicals.

- At the operational level, the current system of mandatory RFCL testing for every consignment creates avoidable delays and disproportionately affects small-lot and specialty imports, such as liquid fertilisers, water-soluble fertilisers and micronutrient blends. These products often move in lower volumes but higher value, where repeated consignment-level testing increases costs, delays market entry, and discourages innovation. Transitioning to a pre-shipment inspection and certification model, as practiced in countries such as Bangladesh and several ASEAN markets, would significantly streamline imports. Under such systems, quality certification is conducted prior to export, with post-sale or risk-based audits ensuring compliance—maintaining standards while reducing administrative friction. Such a shift would lower the compliance burden

for both industry and government, free up laboratory capacity for higher-risk monitoring and improve the predictability of supply chains—particularly important for time-bound agricultural seasons. Importantly, this approach does not dilute quality safeguards, rather, it reallocates regulatory resources more efficiently.

- India should also strengthen the testing ecosystem by allowing importers the flexibility to undertake testing either through RFCL or NABL accredited laboratories. Where importers opt for testing through NABL accredited labs, the associated costs should be borne entirely by the importer. Further, RFCL should also levy nominal testing fee for services rendered. The proceeds can be reinvested towards laboratory modernisation/equipment upgradation and skill development, enabling RFCL to progressively move towards a cost-neutral operational model over time.

  This market-based approach would provide industry with greater flexibility and faster market access while simultaneously strengthening national testing infrastructure, reducing dependence on government budgetary support and creating a sustainable mechanism for continuous capacity building and quality assurance.

6.2.4 Improving data collection and standardization

- Data is foundational to precision nutrition and efficient policy design. Government efforts should focus on strengthening and integrating soil health, crop performance and nutrient use data systems into a unified, interoperable platform. Enhancing the depth, frequency and usability of soil health data can enable more precise nutrient recommendations and better targeting of interventions.

- Creation of a standardized framework for soil testing methods across the country can ensure consistency and reliability of soil diagnostics.

- Open-access, anonymised data platforms can support industry innovation, academic research, and evidence-based policymaking, while safeguarding farmer interests.

- Creation of a central database for biostimulants-Establishing a central, publicly accessible, digital registry of approved products and dossiers would enhance transparency amongst stakeholders and align India's practices with global practices such as Brazil's Ministry of Agriculture, Livestock, and Supply (MAPA) and the EU CE databases.

6.2.5 Creating an enabling policy and regulatory environment

6.2.5.1 Simplified inclusion of innovative speciality nutrients under FCO

- In an ideal regulatory framework, product label claims should be accepted as the primary basis for market approval, without additional prescription under the FCO. This would expand the product basket available to farmers and enable faster market entry of formulations tailored to India's diverse agro-climatic requirements.

  Under such a regime, accountability for claim substantiation, product quality and field performance would rest with manufacturers and marketers. The government's role would be to establish a robust oversight mechanism, including post-market surveillance, randomised quality testing, traceability protocols and a framework to address non-compliance and misrepresentation.

  However, if immediate adoption of label claims is not feasible, a pragmatic alternative in the short term would be to notify general specifications for solid, liquid and micronutrient fertilisers (as has been done for

WSFs). This would ensure baseline standards for composition and quality, while retaining a degree of flexibility for product differentiation within a defined regulatory framework.

The process may be modeled on the already present framework for water-soluble fertilisers, with minimum nutrient content, maximum contaminant and heavy metals thresholds, and registration based on general specifications. The general specifications that may be referred to are provided in exhibit 34.

Exhibit 34: General specification for solid, liquid and micronutrient fertilisers

Solid Macro & Secondary	Liquid Macro (Primary + Secondary)	Micronutrients
Contain at least one of the nutrients, N, P2O5, K2O, Ca, Mg, S or contains one N, P, K and one or more of Ca, Mg, S In case of only one declared primary nutrient, the nutrient content shall be at least the following 10% N 12% P2O5 6% K2O 3% Mg 9% Ca 4% S In case of more than one or more declared primary nutrients N, P, K and one or more secondary macronutrients Ca, Mg, S, then the nutrient content shall be at least the following 3% N 3% P2O5 3% K2O And those of secondary macronutrients shall be at least the following: 1% Mg 1% Ca 0.6% S Total nutrient content of primary and secondary macronutrients shall be at least 18%.	Only one of N, P, K, Ca, Mg, S or One of N, P, K and one or more of Ca, Mg, S In case of only one declared primary nutrient N, P, K, and Ca, Mg, S then the nutrient content shall be at least the following 5% total N 5% P2O5 3% K2O 1% Mg 4% Ca 2% S In case of only one declared primary nutrient N, P, K, and one or more of Ca, Mg, S, then the nutrient content shall be at least the following: Primary nutrient shall at least be following: 1.5% N 1.5% P2O5 1.5% K2O Secondary macronutrients shall be at least the following: 0.5% Mg 0.5% Ca 0.2% S Sum of all declared primary and secondary macronutrients shall at least be 7%.	**Micronutrient based fertiliser** Can be straight or a combination with other micro-nutrients-Min 5% **Micronutrient suspension fertiliser** Suspension of a single micronutrient – Min 2% of a micronutrient suspension fertiliser **Micronutrient Chelates** Single or combination with micronutrients – Min 5% of a chelate shall consist of a water-soluble micronutrient **Micronutrient fortification** Single or a combination of micronutrient fortification for solid inorganic fertilisers – Min 0.2%, except for Molybdenum 0.01%.

Crop nutrition products which are a combination of the guidelines for the individual Solid, Liquid and Micronutrient fertilisers and meet the minimum specifications for each of these categories be allowed.

The general specifications recommended herein have been formulated based on a review of regulatory practices adopted across advanced agricultural economies, including the UK, USA, Canada, and Japan. These countries have a defined baseline of minimum nutrient and maximum contaminants thresholds, thereby promoting the use of clean and quality-assured fertilisers that support improved farm productivity and sustainable agricultural outcomes.

Source: FICCI Taskforce on Innovative Crop Nutrition

Other key actionable in this regard may include:

- New grades may be approved within 60 days on State Marketing Licences. Deemed approved if approval is not received in 90 days.

6.2.5.2 Introduction of One Nation One License system

Introduce a centralized license valid across all states for the manufacture, import and sale of nutrients. This will eliminate the need for multiple state-wise registrations for the same product, formulation or manufacturing unit and improve Ease of Doing Business.

6.2.5.3 Setting up a single window system and enabling digital integration

- A simplified single-window registration and approval system can significantly reduce turnaround time.
- Introducing an end-to-end digital tracking system that provides applicants with real-time visibility into the status of submitted documents and approvals is critical. Approvals may be made time bound and provided within three months of application submission.
- Developing an interoperable, API-enabled digital architecture linking central and state registration and approval systems will enable real-time data sharing, improve coordination and streamline approval workflows.

6.2.5.4 Incorporation of comprehensive sustainability assessment framework

The introduction of a comprehensive sustainability assessment framework for product approval can serve as a transformative step in aligning agricultural innovation with India's long term environmental and climate objectives. Traditionally, product evaluation systems have focused primarily on efficacy, safety and agronomic performance. However, emerging challenges such as climate change necessitate a broader evaluation approach that recognizes the environmental and ecosystem benefits delivered by innovative products.

Such a framework would enable the systematic assessment of products against measurable sustainability indicators, including greenhouse gas (GHG) emission reduction potential, carbon sequestration capacity, enhancement of soil biological and enzymatic activity, improvement in nutrient use efficiency, biofertilization benefits and contribution to soil health restoration. By incorporating these parameters into the regulatory approval process, policymakers can incentivize the development and adoption of technologies that generate positive environmental impact while maintaining agricultural productivity.

6.2.5.5 Introducing a provision under the Fertiliser Control Order (FCO), analogous to Clause 9(3) of the Central Insecticide Board (CIB)

From a trade and competitiveness perspective, India's regulatory framework needs to enable exports of specialty and non-bulk nutrients. Introducing a provision under the Fertiliser Control Order (FCO), analogous to Clause 9(3) of the Central Insecticide Board (CIB), would allow products meant exclusively for export to be registered without mandatory domestic registration—particularly where active ingredients or formulations are not marketed in India[79]. Such a provision would align India with global best practices, reduce entry barriers for export-oriented

[79] CIB allows for a 9(3)export registration in 1 month for active ingredients not registered in India for export.

manufacturers, and help capture lost export opportunities in high-value global markets. Given India's ambitions to position itself as a manufacturing and export hub for agri-inputs, this reform could meaningfully contribute to value-added exports.

6.2.5.6 Fertiliser classification under the Customs Tariff Act

There is an urgent need to harmonize the classification of fertilisers and micronutrients under the Customs Tariff Act to remove ambiguity and ensure regulatory consistency. Currently, bulk fertilisers are classified under Chapter 31, while micronutrients and other innovative nutrient products fall under Chapter 28 (Inorganic Chemicals)—a shift made after 2016 that has led to persistent confusion and misinterpretation. This misalignment has resulted in instances where micronutrients, despite being listed under the fertiliser Control Order (FCO) and used for agricultural purposes, are not recognized as fertilisers for customs or taxation purposes. The root cause lies in the restrictive definition of fertilisers under Chapter 31, which limits inclusion to products containing N, P, or K. To address this, it is recommended that the authorities redefine the scope of Chapter 31 to cover all products approved under the FCO, ensuring uniform treatment across fertiliser categories—bulk, secondary, or micronutrient. This clarification would not only eliminate regulatory and procedural inconsistencies but also prevent revenue disputes and facilitate smoother import, trade, and innovation in the fertiliser sector.

6.2.5.7 Establishing a simplified, predictable, science-led and harmonised regulatory framework for biostimulants

- Regulatory uncertainty and fragmented approval processes remain a key bottleneck for scaling of innovative crop nutrition, particularly for newer categories such as biostimulants. As the segment scales in terms of product diversity, market penetration, and farmer adoption, the continuation of interim or ad hoc regulatory arrangements becomes a constraint. A shift toward clearly articulated, stable, and predictable regulatory frameworks is essential to support long-term industry growth and innovation.

- Introduction of claim-based registration supported by scientific evidence: Moving towards a claim-based registration and scientific labelling framework would allow innovative products to enter the market based on demonstrated functionality rather than rigid product definitions. This approach encourages R&D-led innovation while ensuring transparency and accountability.

- Simplifying trial requirements for known, low-risk ingredients and harmonising standards (in the context of biostimulants) with major global markets (EU, US, Brazil) can further accelerate innovation and international trade. Standardised protocols and mutual recognition of data, where appropriate, would reduce duplication of trials, shorten approval timelines, and signal regulatory maturity to global investors and manufacturers.

- Adopting a material-based categorisation framework for biostimulants—focusing on active ingredients and material characteristics is warranted. Such an approach, inspired by the EU's Component Material Categories (CMC) system, would improve regulatory objectivity, reduce ambiguity in product classification, and provide a more predictable pathway for innovation without diluting safety standards.

- Toxicity and bio-efficacy testing protocols for biostimulants may be standardised and harmonised with established OECD test guidelines and DBT scientific protocols. This would ensure consistent assessment of human, ecological, and food-chain safety, reduce variability in regulatory interpretation, and improve the predictability and efficiency of the approval process without compromising safety.

- A unified bio-Inputs law: A Unified Bio-Inputs Law with clear category definitions can bring regulatory coherence across diverse product segments. However, this can be looked at, over a long term, to avoid immediate disruption. In the near to medium term, a phased convergence approach—focused on harmonising definitions, testing protocols, and approval processes under existing laws—would be a more appropriate pathway for regulatory coherence without disrupting market growth.

- Introduction of structured mechanisms for technical validation of application dossiers—such as standardised checklists, pre-screening, and judicious use of accredited technical institutions/ independent conformity bodies, will help in improving quality, consistency, and credibility of submissions. This would reduce procedural delays, and minimise subjectivity in reviews.

6.2.5.8 Development of framework for nano fertilisers

A comprehensive "Nano Fertilisers" framework to be developed for all nano nutrients. Clause 20D of the FCO may be expanded to include nano forms of phosphorus, potassium, and micronutrients.

6.2.6 Strengthening stakeholder coordination

- **Strengthening inter-ministerial coordination-**A structured coordination mechanism between the Ministry of Agriculture and Farmers' Welfare and Ministry of Chemicals and Fertilisers is essential to align nutrient policy with crop-specific agronomic requirements, evolving farming systems, and national productivity objectives. The current fragmentation between input regulation, subsidy administration, agronomic advisories, and field-level adoption limits the effectiveness of nutrient use strategies and slows the adoption of innovative crop nutrition solutions. A coordinated framework may therefore be established to enable integrated planning, synchronized policy formulation, and real-time information exchange across departments/ministries.

- **Institutionalized stakeholder consultations-** A transparent and consultative regulatory approach is essential before undertaking any policy interventions in the crop nutrition sector. Institutionalized stakeholder consultations (both at central and state levels) involving industry, regulators, academia, and farmer bodies can support the development of calibrated policy responses that address the challenges without adversely impacting compliant and innovation-led businesses. Such an approach would enhance regulatory credibility, improve ease of doing business, and promote sustainable growth of the sector.

Conclusion

To unlock the full value of innovative crop nutrition, it is critical to align the policy intent, with institutional capacity and industry innovation. Bringing regulatory clarity, expanding testing and extension systems, and fostering market-led adoption are important to translate technological potential into measurable farm-level impact. With the right enabling ecosystem, innovative nutrient solutions have the potential to significantly improve productivity outcomes while reducing inefficiencies inherent in conventional fertiliser usage. The recommendations outlined in this report provide a clear roadmap towards this, and collectively, these interventions can reposition crop nutrition from an input-intensive paradigm to a precision and efficiency led agricultural productivity driver. The pace at which India enables and scales innovative crop nutrition will directly determine its ability to achieve sustainable productivity growth, enhance global competitiveness, and secure long-term resilience of its agricultural economy.

Annexure 1:

List of biostimulants approved in India (as of May 2026)

Category	No of products
Humic / Fulvic / Humates- Total products notified 34+	
By form	
Liquid formulations	15
Powder formulations	8
Granule / granular formulations	7
Crystal / flake formulations	3
By Formulation	
Humic acid only products	15
Humic + fulvic products	10
Humic substances / humates / fulvates	9
Dominant source	Leonardite
Emerging trends	Renewable biomass humics, potassium humates, low-dose foliar humics
Seaweed Extracts Total products notified-34+	
By Form	
Liquid formulations	19
Powder formulations	8
Granule formulations	6
Flake formulations	1
By Formulation	
Ascophyllum nodosum products	18
Sargassum spp. products	5
Kappaphycus alvarezii products	2
Gracilaria spp. products	2
Ecklonia maxima products	1
Laminaria digitata products	1
Multi-seaweed blend products	5
Dominant species	Ascophyllum nodosum
Key actives increasingly specified	Alginic acid, fucoidan, mannitol

Category	No of products
Major regulatory trend	High concentration seaweed extracts increasing
Botanical Extracts Total products notified-15+	
By From	
Liquid formulations	13
Powder formulations	2
By Formulation	
Medicago sativa products	2
Camellia sinensis products	2
Tinospora cordifolia products	1
Citrus aurantium products	1
Adhatoda vasica products	1
Spirulina / Arthrospira products	2
Chlorella vulgaris products	1
Mixed botanical products	5+
Major trend	Polyphenol/flavonoid chemistry-based products
Protein Hydrolysates & Amino Acids Total products notified-20+	
By Form	
Liquid formulations	11
Powder formulations	5
Granule formulations	4
By Formulation	
Plant-source hydrolysates	12
Amino acid-specific products	5
Common plant sources	Soybean, corn
Common processing method	Enzymatic hydrolysis
Major trend	Seaweed + amino/protein combinations increasing rapidly
Mixed Formulations Total products notified-18+	
By Form	
Liquid formulations	12

Category	No of products
Powder formulations	1
Granule formulations	5
By formulation	
Seaweed + protein hydrolysate	6
Seaweed + humic combinations	3
Humic + protein hydrolysate	2
Seaweed + vitamin	2
Botanical + seaweed	1
Seaweed + blue-green algae	1
Seaweed + amino acid	1
Fulvic + seaweed + vitamin	1
Seaweed + protein hydrolysate + humic	1
Major trend	Multi-active physiology-modulating formulations increasing
Algae / Cyanobacteria Total products notified-5+	
By From	
Liquid formulations	4
Granule formulations	1
By formulation	
Spirulina / Arthrospira products	2
Chlorella products	1
Blue-green algae mixtures	2
Major trend	Algae increasingly overlapping with botanical biostimulants

Abbreviations

APEDA	Agricultural and Processed Food Products Export Development Authority
AICRP	All India Coordinated Research Project
API	Application Programming Interface
ASEAN	Association of Southeast Asian Nations
Bn	Billion
CAGR	Compound Annual Growth Rate
CCS HAU	Chaudhary Charan Singh Haryana Agricultural University
CE	Conformity Assessment/Marking
CF	Customised Fertiliser
CIB	Central Insecticides Board
CMC	Component Material Categories
CRF	Controlled-Release Fertiliser
DAP	Di Ammonium Phosphate
DBT	Department of Biotechnology
DGFT	Director General of Foreign Trade
DRC	Dealers Registration Certificate
EDTA	Ethylenediaminetetraacetic Acid (a common chelating agent used for micronutrient fertilisers like chelated Zinc or Iron)
EPA	Environmental Protection Agency
EU	European Union
F&V	Fruits & Vegetables
FAI	Fertiliser Association of India
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Database
FCO	Fertiliser (Control) Order

FPO	Farmer Producer Organisation
FY	Financial Year
FYM	Farm Yard Manure
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOI	Government of India
GST	Goods and Services Tax
GVO	Gross Value of Output
Ha	Hectare
HEDP	Hydroxy Ethylidene Di phosphonic Acid (an advanced organophosphorus chelating agent used in stable liquid fertiliser formulations)
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
INR	International Dollar
JNKVV	Jawaharlal Nehru Krishi Vishwa Vidyalaya
Kg	Kilogram
KVK	Krishi Vigyan Kendra
MAPA	Brazil's Ministry of Agriculture, Livestock, and Supply
Mn	Million
MoA&FW	Ministry of Agriculture & Farmers Welfare
MRC	Manufacturers Registration Certificate
MSME	Micro, Small and Medium Enterprises
MT	Metric Tonne
NABARD	National Bank for Agriculture and Rural Development
NABL	National Accreditation Board for Testing and Calibration Laboratories
NBS	Nutrient Based Subsidy
NF	Nano Fertilisers
NPK	Nitrogen Phosphorus Potassium

NUE	Nutrient Use Efficiency
OECD	Organisation for Economic Co-operation and Development
PDMC	Per Drop More Crop
PFC	Product Function Category
PFDC	Precision Farming Development Center
PGPR	Plant Growth-Promoting Rhizobacteria
pH	Potential of Hydrogen (measure of soil acidity or alkalinity)
PIB	Press Information Bureau
PKVY	Paramparagat Krishi Vikas Yojana
PLI	Production Linked Incentive
PMKSY	Pradhan Mantri Kisan Sinchai Yojana
PM-PRANAM	Prime Minister's Program for Restoration, Awareness, Nourishment, and Amelioration of Mother Earth
PRS	Policy Research Studies
R&D	Research and Development
RDA	Recommended Daily Allowance
RDF	Recommended Dose of Fertilisers
RFCL	Regional Fertiliser Control Laboratories
SCRF	Slow/Controlled-Release Fertiliser
SGS	Société Générale de Surveillance (global inspection and testing body)
SRF	Slow-Release Fertiliser
SSP	Single Super Phosphate
TNAU	Tamil Nadu Agricultural University
UPAg	Unified Portal for Agricultural Statistics
USA	United States of America
USD	United States Dollar
WSF	Water Soluble Fertiliser

Acknowledgement

S. No.	Name & Designation	Organization
1	Mr. Sanjiv Kanwar, Chairman, FICCI Task Force on Innovative Crop Nutrition and Managing Director, South Asia & Country Head, India	Yara India
2	Mr. Sanjay Chhabra, Executive Director & Business Head	DCM Shriram Ltd
3	Mr. Robin Edwin, Country Head and Managing Director	Mosaic India
4	Dr. Soumitra Das, Director Asia Pacific – Zinc Nutrient Initiative	International Zinc Association (IZA)
5	Ms. Komal Shah Bhukhanwala, Director – R&D and IP	Sulphur Mills Ltd.
6	Dr. Renuka Diwan, Co-founder & CEO	Bioprime Agrisolutions Pvt. Ltd.
7	Dr. Binaya Kumar Parida, Chief Agronomist	Coromandel International Ltd.
8	Mr. Virendra Goswami, Country Manager	Tessenderlo Kerley International (TKI)

At a Glance - A New Generation Private Sector Bank

At YES BANK, we are driven by a deep purpose and relentless commitment to our customers.

Headquartered in Mumbai, YES BANK is the 6th largest private sector Bank in India offering full-fledged banking solutions with its comprehensive bouquet of product and services, digital solutions catering to Retail, MSME, Wholesale and Rural segments. The Bank has a pan India presence with 1,255 branches, 235 BCBOs and 1,331 ATMs (including CRMs and BNAs) in over 300 districts in India.

The Bank operates its Brokerage business through YES SECURITIES, a wholly-owned subsidiary of the Bank. The Bank has a pan-India presence including an International Banking Unit {IBU) at GIFT City in the Ahmedabad district, Gujarat and a Representative Office in Abu Dhabi. Through a growing pan-India presence, we empower our customers to achieve their full potential and serve India's future businesses.

The Bank's vision rests on three strategic pillars:

Universal Banking with Granular Focus: Maintain our role as a universal bank while concentrating on refining and expanding each business segment.

Digital Leadership and Relationship Banking: Leverage our established digital market leadership to serve the new-age economy and future value pools, ensuring we also support and capture transactional business.

Employee-centric Culture and Efficient Processes: Prioritise an employee-focussed culture, streamline processes, and develop a scalable technology infrastructure.

YES BANK has consistently fostered a strong sustainability ethos within its culture, enabling it to respond effectively to evolving ESG expectations, regulations, and opportunities. The Bank continuously monitors ESG and climate developments, collaborating with stakeholders to integrate key sustainability themes and practices into its operations.

Established in 1927, FICCI is the largest and oldest apex business organisation in India. Its history is closely interwoven with India's struggle for independence, its industrialization, and its emergence as one of the most rapidly growing global economies.

A non-government, not-for-profit organisation, FICCI is the voice of India's business and industry. From influencing policy to encouraging debate, engaging with policy makers and civil society, FICCI articulates the views and concerns of industry. It serves its members from the Indian private and public corporate sectors and multinational companies, drawing its strength from diverse regional chambers of commerce and industry across states, reaching out to over 2,50,000 companies. FICCI provides a platform for networking and consensus building within and across sectors and is the first port of call for Indian industry, policy makers and the international business community.