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Biofertilizers in India: The Promise Is Real, but the Quality-Control Gap Is Larger Than the Marketing

Living inoculants can support nutrient acquisition and crop growth, yet viability, formulation, field fit, and honest labelling determine whether farmers receive a biological input or an empty bottle.

Aakash Achyutrao Dugane[1*], **Amruta Bramhadnyan Ashtekar**[1]

1 Department of Biotechnology and Bioinformatics, Mahatma Gandhi Mission's College of Computer Science and Information Technology, Nanded, Maharashtra, India

*** Corresponding author:** akashdugane0@gmail.com

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ABSTRACT

Biofertilizers contain living microorganisms intended to improve nutrient availability, root growth, or plant performance. India has a long history of products based on Rhizobium, Azotobacter, Azospirillum, phosphate-solubilising microorganisms, mycorrhizal fungi, and other beneficial microbes. These inputs can reduce nutrient losses, support legumes, and complement fertiliser management. However, a biological product is unusually vulnerable to failure between factory and field. Cells may be incorrectly identified, present below the declared count, damaged by heat, stored too long, mixed with incompatible chemicals, or applied to crops and soils where they cannot establish. This Article argues that the core Indian biofertilizer challenge is no longer proving that beneficial microorganisms exist. It is delivering viable, authentic, appropriately formulated organisms with claims supported by local field evidence. Stronger quality systems, cold-chain-aware logistics, strain traceability, farmer instructions, and post-market surveillance are necessary if biofertilizers are to become reliable components of nutrient management rather than low-cost substitutes marketed beyond their evidence.

KEYWORDS biofertilizers; microbial inoculants; India; quality control; rhizobacteria; sustainable agriculture

ARTICLE AT A GLANCE

- Biofertilizers support biological processes; they are not automatic replacements for mineral nutrients.
- Viability at the time of farmer use is more important than cell count at manufacture.
- Strain-crop-soil matching and formulation explain much of the variability in field results.

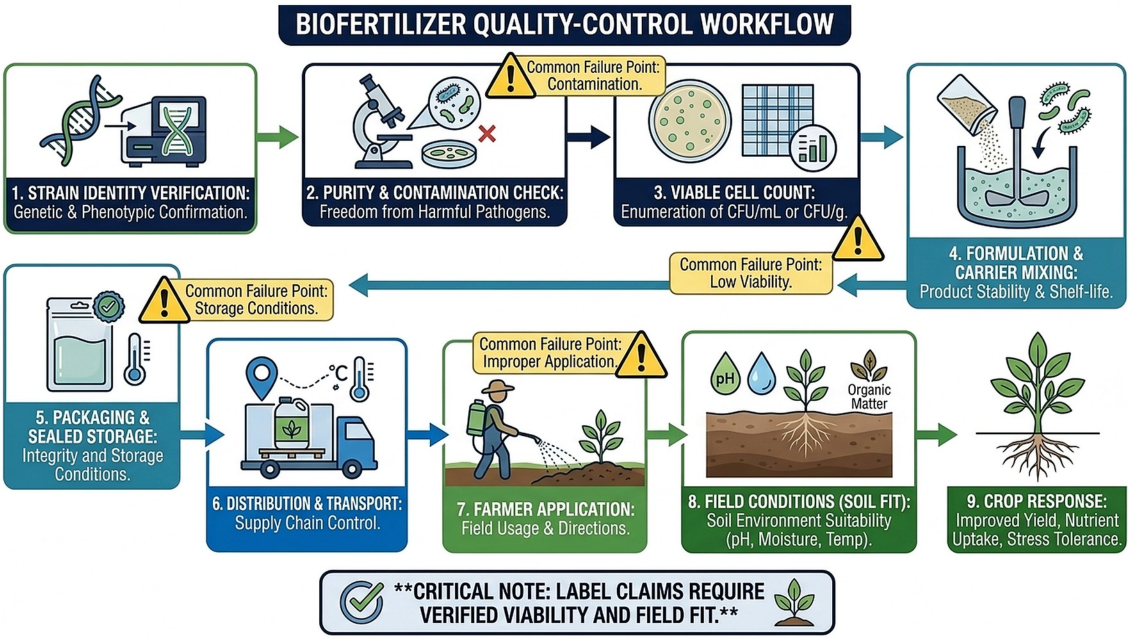

Figure 1. Biofertilizer quality-control workflow from strain identity and contamination checks to formulation, distribution, field performance, and verified product claims.

1. What a biofertilizer can and cannot do

Biofertilizers are not fertilisers in the conventional sense. Most do not supply large quantities of nitrogen, phosphorus, or potassium directly. Instead, they contain microorganisms that may fix atmospheric nitrogen, solubilise or mobilise nutrients, improve root development, or alter the rhizosphere. Rhizobium forms crop-specific symbioses with legumes; Azospirillum and Azotobacter may support nitrogen acquisition and growth; phosphate-solubilising bacteria and fungi can release phosphorus from some compounds; and arbuscular mycorrhizal fungi extend the root’s nutrient-exploring network.

These mechanisms are scientifically established, but their contribution varies. Biological nitrogen fixation in an effective legume symbiosis can be agronomically substantial. By contrast, a free-living bacterium applied to a non-legume may produce a smaller and less consistent effect. Vessey (2003) defined plant growth-promoting rhizobacteria as biofertilizers when they enhance nutrient availability or uptake, but the term is often stretched to include nearly any microorganism associated with growth.

A biofertilizer should therefore be evaluated against a specific claim. Does the product nodulate the intended legume? Does it increase nutrient uptake in the target soil? Can it reduce a defined portion of mineral fertiliser without reducing yield? Does it improve performance only under deficiency, or across ordinary farm conditions? A product that improves early root growth is not automatically a replacement for recommended nutrients. Honest positioning is central to both farmer trust and scientific progress.

2. Why live products fail before application

Unlike a mineral salt, a microbial inoculant can die. Viability depends on strain, carrier, moisture, oxygen, packaging, temperature, and storage duration. India’s supply chains expose products to high ambient temperatures, transport delays, and retail storage without temperature monitoring. A label may declare a high cell count at manufacture while the farmer receives far fewer viable cells months later. Herrmann and Lesueur (2013) identify formulation and quality as persistent constraints in inoculant technology.

Contamination is another risk. If production or packaging is poorly controlled, faster-growing unwanted organisms can replace the intended strain. Morphology alone may not confirm identity, and mixed products are difficult to authenticate. Molecular methods can support strain-level verification, but routine quality control must remain affordable. Minimum tests should include identity, viable count or propagule count, absence of specified contaminants, pH or moisture where relevant, and stability through the claimed shelf life.

Formulation determines whether organisms survive storage and establish after application. Peat, lignite, liquid formulations, polymers, granules, and encapsulation systems offer different protection. Seeds may be treated with fungicides or insecticides that harm inoculants. Mixing instructions, order of application, drying time, and sowing delay can therefore change efficacy. A high-performing strain in research culture can become a poor product if formulation and farmer use are treated as secondary.

3. Field context is as important as product quality

Even a viable and authentic organism may fail in an unsuitable field. Rhizobial strains differ in host compatibility. Soil acidity, salinity, temperature, moisture, nutrient status, and native microbial competition influence colonisation. A phosphate-solubilising organism cannot create phosphorus from nothing; it may help mobilise particular pools under particular chemical conditions. Mycorrhizal benefits may be limited where phosphorus is already abundant or where host crops are weakly responsive.

Field trials should therefore represent the regions and management systems where products are sold. Single-season trials at one research station cannot support nationwide claims. Mahanty et al. (2017) describe the potential of biofertilizers but also emphasise environmental variability and the need for improved production technology. Multi-location testing should include soil properties, climate, crop variety, fertiliser background, irrigation, pesticide use, and baseline microbiology.

Results should report absolute yield, not only percentage increase. A large percentage gain from a very low-yield control may be less useful than a small stable gain in a productive system. Trials should compare the inoculant with recommended fertilisation, reduced fertilisation where claimed, and an appropriate carrier control. Without these comparisons, marketing may attribute ordinary fertiliser or organic-matter effects to the microorganism.

4. India has regulation, but enforcement and traceability matter

India’s Fertiliser (Control) Order includes specifications for recognised biofertilizer categories, creating a legal basis for composition, labelling, and quality. Regulation, however, is only as strong as sampling, laboratory capacity, and consequences for non-compliance. Biological products may deteriorate after leaving the factory, so testing only at the manufacturing site can miss failures during distribution. Post-market sampling should include wholesalers, retailers, and end-of-shelf-life products.

Strain traceability would improve accountability. Labels should identify the organism at an appropriate taxonomic level, strain or consortium designation where possible, viable count at manufacture and expiry, batch number, manufacturing and expiry dates, storage range, target crops, application method, and compatibility warnings. Broad phrases such as “all crops,” “all soils,” or “replaces chemical fertiliser” should require proportionally strong evidence.

The regulatory challenge is not unique to India. Malusá and Vassilev (2014) showed that inconsistent definitions and frameworks complicate biofertilizer markets internationally. India can improve by aligning registration claims with test protocols, requiring evidence for multi-organism products, and building accredited laboratories capable of molecular identity and viability testing. Digital batch verification could help farmers and inspectors confirm product details.

5. From product sales to biological nutrient management

Biofertilizers are most useful as part of integrated nutrient management. Effective Rhizobium inoculation can support legumes; mycorrhizae may assist nutrient acquisition in responsive crops; phosphate-solubilising organisms may complement soil amendments; and plant growth-promoting bacteria may improve establishment under defined stresses. These contributions should be combined with soil testing, organic-matter management, balanced fertilisation, crop rotation, and water management.

Extension is essential because application is biological. Farmers need instructions in local languages and formats that explain storage, compatibility, timing, and realistic outcomes. Demonstrations should show both successful and unsuccessful conditions. Dealers should not be the only source of technical advice. Universities, Krishi Vigyan Kendras, farmer-producer organisations, and independent laboratories can create feedback loops between field performance and registration.

India does not need more bottles labelled “beneficial microbes” unless those bottles reliably contain what they claim. The sector’s credibility will grow when quality at expiry, strain identity, field fit, and claim-specific evidence become visible to farmers. Biofertilizers can support sustainable agriculture, but biology cannot be regulated or marketed as if it were an inert commodity. The product is alive, the field is variable, and the evidence must reflect both realities.

6. A minimum evidence standard for the market

A national minimum evidence standard could classify claims into levels. Level one would confirm identity, viability, contamination limits, and shelf stability. Level two would demonstrate a defined mechanism under controlled conditions. Level three would show crop response in replicated field trials across representative soils and seasons. Level four would support a fertiliser-reduction or yield-stability claim through direct comparison with recommended practice. Labels and advertisements should not imply a higher level than the submitted evidence.

Consortia deserve special scrutiny because the presence of several names on a label does not prove that all members survive together or contribute to performance. Manufacturers should demonstrate each member at expiry, compatibility during storage, and the reason for combining them. When the claimed mechanism depends on interaction among strains, trials should compare the consortium with individual components to show that the mixture adds value.

Post-market surveillance can use risk-based sampling. Products with high sales, broad claims, repeated complaints, or poor storage conditions should be prioritised. Results can be published by batch and manufacturer after due process, creating incentives for quality. Farmer complaint systems should record crop, soil, storage, application, and batch details so failures can be investigated scientifically rather than dismissed as either fake product or farmer error without evidence.

7. Economics and farmer trust

Quality reform must be economically realistic. Molecular authentication, stability studies, and multi-location trials add cost, but unreliable products impose hidden costs on farmers and on credible manufacturers. Public laboratories and shared testing facilities can reduce the burden for small producers while keeping standards intact. Procurement programmes should avoid selecting only the lowest-priced product and instead consider verified viable count, evidence level, shelf-life performance, and complaint history. Farmers should have access to batch-specific test information and a simple route for refunds or investigation when products fail basic specifications. Trust will not be restored through awareness campaigns alone. It will grow when the market rewards manufacturers that maintain living organisms through the final day of shelf life and penalises claims that exceed the evidence.

Key takeaways

- Biofertilizers support biological processes; they are not automatic replacements for mineral nutrients.
- Viability at the time of farmer use is more important than cell count at manufacture.
- Strain-crop-soil matching and formulation explain much of the variability in field results.
- Post-market testing and traceable labels are necessary for meaningful enforcement.
- Biofertilizers work best within integrated nutrient and soil-health management.

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