ISSN: 2393-8048
International Advance Journal of Engineering, Science and Management (IAJESM)
Multidisciplinary, Multilingual, Indexed, Double Blind, Open Access, Peer-Reviewed, Refereed-International Journal.
SJIF Impact Factor = 8.35, July-December 2026, Submitted in October 2026

# Biofertilizers and Biopesticides for Sustainable Agriculture: Evidence, Farm Economics, Ecological Benefits and Implementation Challenges

Krishna Mandla, Research Scholar, Department of Botany, Faculty of Science, Khaja Bandanawaz University, Kalaburagi.
Corresponding author: Krishna Mandla | Email: krishnavmandla@bldea.in
R. B. Hujaratti, Associate Professor, Department of Botany, B.K. College of Arts, Science and Commerce, Belagavi, Karnataka, India

## Abstract

The sustainability of intensive agriculture depends on maintaining crop productivity while improving nutrient-use efficiency, limiting avoidable pesticide exposure and protecting soil and associated biodiversity. Biofertilizers use beneficial microorganisms to support nutrient acquisition and plant growth, whereas biopesticides employ microorganisms, botanical compounds, viruses or other biological agents to suppress selected pests and pathogens. This review critically synthesises evidence on their mechanisms, field performance, technological development, ecological implications and farm-level economics. A global meta-analysis of field studies reported an average yield increase of approximately 16.2% following biofertilizer inoculation, while response varied substantially with climate, soil conditions and inoculant traits [1]. An Indian tomato study of integrated pest and disease management reported 46.15% higher yield, 21.24% lower cultivation cost and 119.21% higher net returns among adopting farms than non-adopting farms; however, the intervention combined multiple practices and cannot attribute the entire effect to biopesticides alone [2]. These findings indicate that biological inputs can generate agronomic and economic value, but outcomes are context-dependent rather than guaranteed. The review identifies inconsistent field efficacy, product viability, quality assurance, farmer awareness, availability and inadequate long-term ecological evaluation as major barriers. It proposes a transparent farm-level economic framework and priorities for regional validation in Indian cropping systems. Biological inputs are best treated as components of integrated nutrient and pest management, supported by quality control, extension services and locally replicated evidence.

**Keywords: biofertilizers; biopesticides; farm economics; integrated pest management; microbial consortia; sustainable agriculture**

## 1. Introduction

Modern crop production has benefited from mineral fertilisers and chemical pesticides, but inefficient or excessive use can contribute to nutrient losses, water contamination, pesticide residues, resistance evolution and effects on non-target organisms. The challenge is not to reject all synthetic inputs, but to improve input efficiency and reduce avoidable environmental and economic costs through integrated approaches [3,4]. Biological inputs have attracted attention because they can complement crop nutrition and protection through biological processes.

Biofertilizers are formulations containing living microorganisms that improve nutrient availability or plant growth when applied to seed, roots, plant surfaces or soil. Important groups include rhizobia, free-living and associative nitrogen fixers, phosphate-solubilising bacteria, potassium-mobilising organisms and arbuscular mycorrhizal fungi. Biopesticides include microbial insecticides, entomopathogenic fungi, microbial antagonists, botanical compounds, baculoviruses and semiochemicals. Some microorganisms can provide overlapping functions, such as plant growth promotion and suppression of selected pathogens [3-7].

Despite their promise, performance varies by crop genotype, soil properties, moisture, temperature, product formulation, strain viability, pest pressure and application timing. Reviews of plant growth-promoting bacteria and biopesticides identify inconsistent field efficacy, shelf-life problems and cost or delivery constraints as persistent obstacles to wider adoption [4,8]. For farmers, the relevant question is therefore not simply whether a product is "biological", but whether it provides a repeatable net benefit under local conditions.

This review connects biological mechanisms with field evidence, economic outcomes and implementation barriers, with particular relevance to Indian agriculture and to region-specific evaluation in Karnataka.

## 2. Review of literature

### 2.1 Biofertilizers: mechanisms and agronomic evidence

Plant growth-promoting rhizobacteria can influence plant performance through biological nitrogen fixation, nutrient solubilisation, siderophore production, phytohormone modulation and interactions with root-associated microbial communities. Vessey's foundational review positioned PGPR as potential biofertilizers but emphasised that mechanisms and practical benefits differ among organisms and conditions [3]. Rhizobial inoculants are most relevant to compatible legume hosts; Azotobacter and Azospirillum are used in broader crop contexts, although their contribution to crop nitrogen demand must be demonstrated rather than assumed. Phosphate-solubilising organisms may increase availability of selected phosphorus compounds, while arbuscular mycorrhizal fungi extend the effective absorptive area of roots through fungal hyphae. These processes are influenced by soil pH, nutrient status, organic matter, indigenous microbial communities and host compatibility [5,6]. A global meta-analysis synthesising field evidence from 171 publications reported average yield responses that differed by climate: approximately 20.0% in dry climates, 14.9% in tropical climates, 10.0% in oceanic climates and 8.5% in continental climates. Across crop categories, the average yield increase was 16.2% [1]. These are pooled study-level estimates, not predictions for every farm; the authors also reported that soil phosphorus and inoculant functional traits influenced outcomes.

A later global network meta-analysis of 1,791 observations from 186 studies found positive average effects of bioeffectors on plant growth, yield and selected quality measures, while also documenting variation by product class and context [9]. Such meta-analyses support the potential of biological inputs but should not be used as universal yield promises. Differences in experimental design, crop species, soil fertility, formulation and climate make local field validation essential.

### 2.2 Biopesticides and biological pest suppression

Biopesticides act through several mechanisms: toxin-mediated insect control, infection of susceptible insects, competition with pathogens, antibiosis, mycoparasitism, induced plant defence, repellence or disruption of pest behaviour. Bacillus thuringiensis products target susceptible insect groups; Beauveria and Metarhizium species infect susceptible insects; Trichoderma and selected bacterial strains can suppress some plant pathogens; neem-derived azadirachtin affects feeding and development in susceptible pests; and baculoviruses can provide targeted control of certain insect species [7,8,10].

Glare and colleagues observed that biopesticides had gained technical and commercial progress, but variable efficacy, high costs and inconsistent field performance continued to restrict adoption [8]. Srinivasan's review of vegetable-legume and brassica systems in Asia and Africa similarly places biopesticides within broader sustainable pest-management programmes rather than as stand-alone replacements for all chemical controls [10]. Biological products are most defensible when used with pest monitoring, resistant varieties, crop rotation, habitat management and judicious intervention thresholds.

### 2.3 Microbial consortia, formulations and emerging technologies

Microbial consortia combine organisms intended to provide complementary functions, for example nutrient mobilisation, root growth promotion and disease suppression. Vishwakarma and colleagues reviewed plant–microbe interactions and the potential of consortia for sustainable agriculture [5]. Nunes and colleagues, however, stress that product development must address strain compatibility, stability, production and reliable performance in real settings

[11]. A mixture is not inherently superior to a single strain: organisms can inhibit each other, compete for resources or fail to establish in a new soil environment.

Recent reviews discuss sequencing, microbiome profiling, improved carriers, encapsulation and synthetic microbial communities as routes to better strain selection and product persistence [4,12,13]. These approaches may improve product design, but genomic identification or a positive laboratory assay is not equivalent to a demonstrated yield or income benefit. Products need viable-count standards, contamination testing, storage validation and replicated field trials.

**2.4 Economic and farmer-level evidence**

Economic outcomes depend on both added revenue and changes in total costs. Biological inputs may reduce the number of chemical sprays or improve yields, but they may also require additional applications, labour, scouting, storage or specialised equipment. An Indian economic analysis of tomato integrated pest and disease management reported yields of 65,349 kg/ha on adopting farms compared with 44,715 kg/ha on non-adopting farms; cultivation costs were ₹86,641/ha and ₹110,008/ha, respectively. Net returns were ₹230,734/ha versus ₹105,258/ha, and benefit–cost ratios were 3.66 and 1.95 [2]. The package included trap cropping, neem/pongamia inputs, a biopesticide and other measures; it therefore demonstrates the potential value of integrated management, not the isolated effect of a single biological product.

More recent farmer-participatory research on integrated pest management in basmati rice reported 8.48% higher grain yield, 15.60% lower cultivation cost and 29.51% higher net return compared with farmer practice, alongside fewer pesticide applications and greater spider abundance [14]. A 2026 farmer-participatory maize study also reported improved yield and net returns under an IPM package [15]. Such field studies are useful because they assess management packages under farm conditions, but their results remain crop-, location-, season- and intervention-specific.

**2.5 Environmental and biodiversity considerations**

Appropriately selected biological inputs may reduce reliance on broad-spectrum pesticides, support nutrient cycling and help preserve natural enemies. Yet non-target effects cannot be dismissed solely because an input is biological. Effects depend on organism identity, exposure, application rate, persistence and the ecological role of the exposed species [7,8,16]. Environmental claims should be supported by targeted assessment of pollinators, predators, parasitoids, soil organisms and water pathways where relevant. The goal should be a demonstrable reduction in overall risk, not merely a change in product category.

**3. Research gaps and objectives**

The literature identifies several unresolved issues. First, laboratory performance is often more consistent than field performance, and regional evidence is uneven. Second, many studies report yield or disease suppression but omit full costs, labour requirements, product shelf life and farmer net returns. Third, the economic outcomes of combined IPM packages are sometimes incorrectly attributed to one biological product. Fourth, long-term effects on non-target organisms and soil microbial functions are not consistently measured. Fifth, quality assurance, storage, availability and extension support affect adoption as much as biological efficacy [4,8,11,16].

The objectives of this review were to: (i) synthesise the principal mechanisms and categories of biofertilizers and biopesticides; (ii) assess quantitative evidence on yield response and farm economics; (iii) examine ecological benefits and possible risks; (iv) identify technical, economic and adoption barriers; and (v) propose a practical framework for region-specific evaluation in Indian agriculture.

**4. Materials and methods**

A structured critical review was conducted using the supplied manuscript as an initial topic

map and expanding it through targeted searches of scholarly publisher pages, PubMed/PMC records and indexed literature. Search terms included "biofertilizer", "plant growth-promoting rhizobacteria", "microbial inoculants", "biopesticide", "integrated pest management", "microbial consortia", "farm economics", "net returns", "benefit–cost ratio" and "sustainable agriculture". Priority was given to peer-reviewed reviews, meta-analyses and field studies reporting agronomic, economic or ecological outcomes. Foundational literature was retained where needed to explain mechanisms; recent studies were used to discuss formulation and implementation challenges.

Evidence was synthesised narratively and organised into four domains: biological mechanisms, field performance, farm economics, and ecological/implementation considerations. Quantitative values are reported only where an identifiable source provided them, with the relevant context and limitations. Studies evaluating integrated management packages are explicitly distinguished from studies testing a single biofertilizer or biopesticide. No new field experiment, farmer survey or original statistical meta-analysis was conducted for this paper.

This is a structured critical review and does not claim full PRISMA 2020 compliance. A PRISMA systematic review requires a reproducible search log, record deduplication, documented screening decisions, full-text exclusion reasons and verified flow counts. These records were not available from the original draft, so screening numbers have not been invented. PRISMA 2020 is a reporting guideline and cannot substitute for carrying out and documenting the underlying review process [17].

## 5. Findings and observations

### 5.1 Evidence of agronomic response

Across the literature, biofertilizers show a positive average yield response, but effect size is conditional. The global field-study meta-analysis reported 16.2% average yield increase, with higher average responses in dry and tropical climate categories than in oceanic and continental categories [1]. These pooled estimates are useful for framing expectations but do not guarantee similar results in Vijayapura, Belagavi or any particular crop. Soil nutrient status, inoculant traits and water regime need to be recorded in local trials.

### 5.2 Economic evidence from Indian field settings

The tomato IPM study provides a clear example of the potential financial value of integrated management: adopting farms had a reported benefit–cost ratio of 3.66 compared with 1.95 for non-adopting farms, and net returns were more than twice as high [2]. The rice IPM study reported a benefit–cost ratio of 2.80 compared with 2.17 under farmer practice, with 29.51% higher net returns [14]. These findings support the economic relevance of integrated biological and cultural approaches, but they cannot be interpreted as a universal return from purchasing biofertilizer or biopesticide products. Differences in crop prices, pest pressure, labour costs and the complete management package matter.

### 5.3 Recurrent implementation constraints

The most consistent constraints are product quality and viability, climate- and soil-dependent performance, lack of reliable application guidance, inconsistent local availability, and limited farmer confidence after variable results. Microbial formulations must maintain sufficient viable organisms through manufacture, transport and storage. Biopesticides may require correct timing, repeated monitoring or environmental conditions that support activity. These requirements create a need for quality assurance, extension services and field demonstration rather than promotional claims alone [4,8,11,12].

### 5.4 Observations for regional research

For northern Karnataka, the evidence supports prioritising field trials in locally important crops and documenting the full treatment package. Trials should report product name and strain where available, batch and expiry details, application rate, soil characteristics, weather, pest pressure, yield, labour and input costs, and non-target observations. Without these details,

apparent differences between farms may reflect management, soil or seasonal differences rather than the biological input itself.

## 6. Results and discussion

### 6.1 Comparative functions and limitations

| Input group | Main function | Potential farm benefit | Main limitation to test |
|---|---|---|---|
| Nitrogen-fixing inoculants | Biological N fixation and plant growth support | May complement nitrogen management, particularly in compatible crop systems | Host compatibility, soil N, survival and actual N contribution |
| Phosphate-solubilising microbes | Mobilisation of some soil P pools | May improve P availability and nutrient-use efficiency | Response depends on soil chemistry and P status |
| Arbuscular mycorrhizal fungi | Hyphal exploration and nutrient uptake | May support P uptake and selected stress responses | Host/fungus compatibility and soil conditions |
| Microbial biopesticides | Pathogen or insect suppression | May reduce selected pesticide applications | Target specificity, timing, storage and field persistence |
| Botanical/biochemical agents | Repellence, feeding/development effects or behaviour modification | Can add selective tools to IPM | Formulation, exposure, persistence and non-target assessment |
| Integrated management package | Combines biological, cultural, monitoring and selective chemical methods | May reduce avoidable sprays and improve net returns | Requires coordination, training and local validation |

The key distinction is between a biological mechanism and a verified farm outcome. Nitrogen fixation, phosphorus mobilisation or pathogen antagonism may be mechanistically plausible, but farmers need evidence that the formulation establishes, performs consistently and improves net returns under their production conditions. This is why product identity, application guidance and field-level quality assurance are central to successful adoption [3,4,11].

### 6.2 Farm economics: how to report cost-efficiency responsibly

A robust economic comparison should use the same crop, season, land area and market-price basis for the biological-input treatment and the comparator. The minimum indicators are: total variable cost (₹/ha), yield (kg/ha), gross return (₹/ha), net return (₹/ha), incremental net return, and benefit–cost ratio. For a consistent definition, net return = gross return − total cultivation cost; incremental net return = net return under treatment − net return under comparator. Benefit–cost ratio must be defined explicitly because studies differ in whether they divide gross returns or net benefits by costs.

A simple break-even test can be used before recommending a product. If the extra cost of the biological programme is $\Delta C$ and the farm-gate crop price is P, the additional yield required to recover that cost is $\Delta Y = \Delta C/P$, provided other costs and quality differences are unchanged. If the programme also reduces pesticide expenditure or labour, those savings should be added to the economic calculation. This is a decision framework, not an estimate of actual savings.

For illustration only, consider a hypothetical farm where a biological-input programme costs an additional ₹1,200/ha and the crop sells for ₹25/kg. The programme would need an additional 48 kg/ha to recover that added cost if yield is the only changed factor (₹1,200 ÷ ₹25/kg). This is a mathematical example, not an observed field result or a claim about current product prices. In a real study, the calculation must use verified local quotations, measured yield and recorded labour and application costs.

| Economic indicator | Calculation | Interpretation |
|---|---|---|
| Gross return | Yield × farm-gate price | Revenue before costs |
| Net return | Gross return − total cultivation cost | Amount remaining after recorded costs |
| Incremental net return | Treatment net return − comparator net return | Additional gain attributable to the full tested package, subject to study design |
| Benefit–cost ratio | State the exact numerator and denominator used | Useful only when definitions are comparable |
| Break-even yield gain | Additional programme cost ÷ crop price | Minimum extra yield required to recover extra cost, if other factors are unchanged |
| Pesticide-cost saving | Comparator pesticide cost − treatment pesticide cost | Must include all substitute products and application costs |

### 6.3 Implications for farmers and extension services

The evidence suggests that biological products are most likely to benefit farmers when they address a clearly diagnosed nutrient limitation or pest problem, are applied correctly, and are integrated into a broader crop-management plan. Extension programmes should communicate realistic expectations, demonstrate correct storage and application, and provide locally relevant comparisons of net return rather than relying only on plant-growth photographs or laboratory results. Product access and quality assurance are essential; farmers cannot benefit consistently from an input that has lost viability or is unsuitable for their crop.

### 6.4 Environmental benefits require outcome-based evaluation

Reduced chemical application can be an important benefit, but studies should measure the change rather than infer it from product labels. Relevant indicators include number and quantity of pesticide applications, residues where feasible, abundance of selected natural enemies, soil biological indicators and crop yield. Integrated programmes can create co-benefits when pest control improves while natural enemies are conserved, as reported in the farmer-participatory rice IPM study [14]. Nonetheless, effects must be evaluated for the actual agent, crop and ecosystem.

## 7. Recommendations and future research

First, conduct replicated on-farm trials across seasons and soil types, using untreated or farmer-practice controls and clearly described integrated treatments. Second, publish full economic budgets alongside agronomic results, including product, labour, machinery, transport and repeat-application costs. Third, test product viability at purchase and after realistic storage periods. Fourth, assess non-target effects and document reductions in pesticide use where these are claimed. Fifth, establish extension demonstrations and farmer feedback mechanisms to identify practical barriers. Sixth, researchers should distinguish single-product effects from the effects of multi-component management packages. For Karnataka, a crop-specific evaluation involving major local crops and locally available registered products would provide stronger decision support than general claims drawn from unrelated agroecological zones.

## 8. Conclusion

Biofertilizers and biopesticides offer scientifically credible tools for improving nutrient management and suppressing selected pests and pathogens, but their contribution to sustainable

agriculture depends on product quality, biological compatibility, environmental conditions and correct use. Global meta-analyses show positive average agronomic responses, while Indian field studies of integrated pest management demonstrate that well-designed packages can improve net returns and reduce cultivation costs. These results should not be converted into universal promises for any single product. The most important next step is transparent, locally replicated evaluation that reports yield, full costs, net returns, pesticide use and ecological indicators together. Biological inputs should be promoted as evidence-based components of integrated nutrient and pest management, not as automatically harmless or universally effective replacements for conventional inputs.

Declarations

Funding: No external funding specifically for preparation of this review was reported.

Conflict of interest: The authors declare no Conflict of interest.

Author contributions: Both authors hold equal contribution.

Data availability: No new experimental dataset was generated. Quantitative findings are drawn from the cited literature.

Ethics approval: Not applicable; this review did not involve new experiments on humans or animals.

Use of illustrative calculation: The break-even example in Section 6.2 is explicitly hypothetical and is not presented as observed field data.

References

1. Schütz L, Gattinger A, Meier M, Müller A, Boller T, Mäder P, et al. Improving crop yield and nutrient use efficiency via biofertilization—a global meta-analysis. Front Plant Sci. 2018; 8:2204. doi:10.3389/fpls.2017.02204.
2. Gajanana TM, Krishna Moorthy PN, Anupama HL, Raghunatha R, Prasanna Kumar GT. Integrated pest and disease management in tomato: an economic analysis. Agric Econ Res Rev. 2006;19(2):269-280. doi: 10.22004/ag.econ.57763.
3. Vessey JK. Plant growth promoting rhizobacteria as biofertilizers. Plant Soil. 2003;255(2):571-586. doi:10.1023/A:1026037216893.
4. Fadiji AE, et al. Formulation challenges associated with microbial biofertilizers in sustainable agriculture and paths forward. J Sustain Agric Environ. 2024. doi:10.1002/sae2.70006.
5. Vishwakarma K, Kumar N, Shandilya C, Mohapatra S, Bhayana S, Varma A. Revisiting plant–microbe interactions and microbial consortia application for enhancing sustainable agriculture: a review. Front Microbiol. 2020; 11:560406. doi:10.3389/fmicb.2020.560406.
6. Shahwar D, Mushtaq Z, Mushtaq H, et al. Role of microbial inoculants as bio fertilizers for improving crop productivity: a review. Heliyon. 2023;9(6): e16134. doi: 10.1016/j.heliyon.2023.e16134.
7. Shahzad M, Hayat R, Mujtaba G, Rehman WU, Nadeem M. Biofertilizers in sustainable agriculture: mechanisms, applications, and future prospects. Discov Agric. 2025; 3:224. doi:10.1007/s44279-025-00318-0.
8. Glare T, Caradus J, Gelernter W, Jackson T, Keyhani N, Köhl J, et al. Have biopesticides come of age? Trends Biotechnol. 2012;30(5):250-258. doi: 10.1016/j.tibtech.2012.01.003.
9. Schütz L, et al. A global network meta-analysis of the promotion of crop growth, yield, and quality by bioeffectors. Front Plant Sci. 2022. See PubMed record: PMID 35300013.
10. Srinivasan R. Biopesticide based sustainable pest management for safer production of vegetable legumes and brassicas in Asia and Africa. Pest Manag Sci. 2019. doi:10.1002/ps.5480.
11. Nunes PSO, Lacerda-Junior GV, Mascarin GM, Guimarães RA, Medeiros FHV, Arthurs S, et al. Microbial consortia of biological products: do they have a future? Biol Control. 2024; 188:105439. doi: 10.1016/j.biocontrol.2024.105439.

12. Samantaray A, Chattaraj S, Mitra D, Ganguly A, Kumar R, Gaur A, et al. Advances in microbial based bio-inoculum for amelioration of soil health and sustainable crop production. Curr Res Microb Sci. 2024; doi: 10.1016/j.crmicr.2024.100251.
13. Singh M, Jha S, Pathak D, et al. Advancing biofertilizers: the evolution from single-strain formulations to synthetic microbial communities (SynCom) for sustainable agriculture. Discov Plants. 2025; 2:226. doi:10.1007/s44372-025-00318-w.
14. Choudhary M, Singh SK, et al. Large scale validation and refinement of integrated pest management strategy for basmati rice (Oryza sativa) in farmers' participatory mode. Indian J Agric Sci. 2025;95(12). doi:10.56093/ijas. v95i12.163712.
15. Indian Council of Agricultural Research authors. Large scale field validation of integrated pest management strategies in maize (Zea mays) through farmers' participatory approach. Indian J Agric Sci. 2026. Article record published in 2026; verify final volume, issue and pages before submission.
16. Baker BP, Green TA, Loker AJ. Biological control and integrated pest management in organic and conventional systems. Biol Control. 2020; 140:104095. doi: 10.1016/j.biocontrol.2019.104095.
17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372: n71. doi:10.1136/bmj. n71.
18. Bashan Y, de-Bashan LE. How the plant growth-promoting bacterium Azospirillum promotes plant growth—a critical assessment. Adv Agron. 2010; 108:77-136. doi:10.1016/S0065-2113(10)08002-8.
19. Richardson AE, Barea JM, McNeill AM, Prigent-Combaret C. Acquisition of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. Plant Soil. 2009; 321:305-339. doi:10.1007/s11104-009-9895-2.
20. Compant S, Clément C, Sessitsch A. Plant growth-promoting bacteria in the rhizo- and endosphere of plants: their role, colonization, mechanisms involved and prospects for utilization. Soil Biol Biochem. 2010;42(5):669-678. doi: 10.1016/j.soilbio.2009.11.024.
21. Raaijmakers JM, Mazzola M. Soil immune responses. Science. 2016;352(6292):1392-1393. doi:10.1126/science. aaf3252.
22. Köhl J, Kolnaar R, Ravensberg WJ. Mode of action of microbial biological control agents against plant diseases: relevance beyond efficacy. Front Plant Sci. 2019; 10:845. doi:10.3389/fpls.2019.00845.
23. Glare TR, O'Callaghan M. Bacillus thuringiensis: biology, ecology and safety. Chichester: John Wiley & Sons; 2000.
24. Bale JS, van Lenteren JC, Bigler F. Biological control and sustainable food production. Philos Trans R Soc Lond B Biol Sci. 2008;363(1492):761-776. doi:10.1098/rstb.2007.2182.
25. Pretty J, Bharucha ZP. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects. 2015;6(1):152-182. doi:10.3390/insects6010152.
26. Gurubasajar N, Basaiah T. Integrating microbial consortia into biofertilizers for sustainable agriculture: enhancing plant productivity and soil health. Arch Agric Environ Sci. 2025;10(1):157-163. doi:10.26832/24566632.2025.1001023.