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Role of Farmer Education in Promoting Biopesticides and Reducing Chemical Pesticide Use

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The transition from routine chemical pesticide use toward integrated and biologically based crop protection depends not only on the availability of biopesticides but also on farmers' knowledge, confidence, decision-making skills and access to credible extension support. This paper examines the role of farmer education in promoting biopesticides and reducing unnecessary reliance on chemical pesticides, with particular emphasis on the National Service Scheme (NSS) as a community-oriented platform for knowledge dissemination. The paper uses a literature-informed, practice-oriented framework rather than presenting fabricated field results. It synthesizes the principles of integrated pest management (IPM), Farmer Field School learning, Indian agricultural extension experience and NSS objectives to identify educational pathways through which farmers can learn pest identification, economic-threshold-based decisions, safe pesticide handling, biological control, botanical products and correct use of registered biopesticides. The proposed NSS intervention model combines baseline knowledge assessment, village meetings, crop-specific demonstrations, field observation, visual learning materials, school and youth engagement, farmer-to-farmer learning and follow-up evaluation. Particular attention is given to barriers such as inconsistent product quality, limited knowledge of application timing, misconceptions that biopesticides are automatically harmless, delayed visible action compared with some conventional pesticides, inadequate storage and weak technical support. The paper argues that farmer education should not be framed as a simple substitution of one input for another; instead, it should build ecological literacy and support IPM decisions in which biological, cultural, mechanical and chemical measures are combined according to need. NSS volunteers can complement, rather than replace, the technical roles of Krishi Vigyan Kendras (KVKs), State Agricultural Universities, extension departments and plant-protection specialists. A structured education-and-demonstration approach can therefore contribute to more informed pesticide decisions, improved acceptance of biopesticides and safer, more sustainable crop protection.

Keywords: Farmer education, Biopesticides, Integrated Pest Management, Chemical pesticide reduction, Sustainable agriculture.

Introduction and Background

Crop protection is a knowledge-intensive component of modern agriculture. Farmers must distinguish pests from beneficial organisms, understand crop-stage susceptibility, assess pest pressure and choose an intervention that is technically effective, economically justified and safe for people and the environment. Integrated Pest Management (IPM) is designed around this decision-making process. Current ICAR guidance describes IPM as an approach that combines cultural, physical, mechanical, varietal, biological, bio-rational, biotechnological and chemical measures, with non-chemical methods prioritized and pesticides used only when necessary and at recommended doses. Biopesticides can form an important part of this approach. Depending on the product and regulatory category, they may include microbial agents, botanical preparations and other biologically derived pest-management products. Examples used in crop protection research and extension include *Trichoderma*, *Beauveria*, *Lecanicillium* and neem-based products. Their successful use is highly dependent on correct product selection, target-pest identification, formulation quality, dose, application timing, environmental conditions and compatibility with other IPM practices. ICAR has documented field demonstrations and research involving microbial and botanical biopesticides, including demonstrations aimed at improving farmer awareness.

The central problem is therefore not simply that farmers lack access to alternatives. In many situations, farmers receive fragmented information from input dealers, neighboring farmers, product labels, social media and extension agencies. When pest outbreaks are sudden, the perceived speed and certainty of conventional chemical sprays can make them attractive. Education can alter this decision environment by teaching farmers how to monitor crops, recognize beneficial organisms, understand economic thresholds and evaluate alternatives before a spray becomes the default response. The NSS provides a potentially useful community interface for such education. The official NSS programme describes its purpose as 'Education through Service' and emphasizes linkages among campus, community, college, village, knowledge and action. Its objectives include identifying community problems, applying knowledge to practical solutions and mobilizing community participation.

Objectives

1. To examine how farmer education can influence awareness, confidence and adoption of biopesticides within an IPM framework.
2. To identify the major knowledge and implementation barriers that encourage unnecessary or poorly timed chemical pesticide use.
3. To develop an NSS-oriented extension model for crop-specific farmer education, demonstration and follow-up.
4. To propose measurable indicators for evaluating changes in farmer knowledge, pesticide decision-making and biopesticide adoption.
5. To clarify the complementary roles of NSS volunteers, agricultural experts, KVKs, universities, extension departments and farmer groups.

Methods and Materials

Study design: The present paper is a literature-informed conceptual and extension-planning study. It uses the structure of the supplied NSS research article as a model for organization, while avoiding unsupported claims of original field measurements. The analysis draws on official NSS guidance, ICAR material on IPM and biopesticide demonstrations, FAO guidance on Farmer Field Schools and pesticide-risk reduction, and Indian regulatory information concerning biopesticides. The proposed intervention is designed for rural agricultural villages and can be adapted to crops such as vegetables, rice, pulses, fruit crops and other locally important crops. A participatory sequence is recommended: (1) baseline assessment; (2) farmer problem identification; (3) classroom or village-level learning; (4) field demonstration; (5) farmer observation and practice; and (6) follow-up assessment. This mirrors the practical, field-based learning logic of Farmer Field Schools, in which farmers

regularly observe crop ecosystems, conduct simple experiments and use group discussion to improve decisions.

Table 1: Proposed NSS Farmer-Education Intervention Framework

Phase	Core activity	NSS role	Technical partner	Expected learning outcome
1. Baseline	Short survey on pest knowledge, spray frequency, current alternatives and safety practices	Household contact and data collection	KVK/SAU/extension specialist	Initial knowledge and practice profile
2. Problem identification	Village crop walk and participatory pest/problem mapping	Mobilize farmer groups	Plant-protection expert	Locally relevant pest priorities
3. Classroom learning	Pest identification, beneficial insects, IPM, biopesticide concepts and safe use	Facilitation and visual communication	Subject-matter specialist	Improved conceptual understanding
4. Demonstration	Crop-specific demonstration of monitoring, biological/botanical options and correct application	Organize field day and attendance	KVK/SAU/qualified trainer	Practical confidence and correct technique
5. Farmer practice	Farm observation, decision records and farmer-to-farmer discussion	Follow-up visits	Extension staff	Improved decision-making
6. Evaluation	Post-training test, practice checklist and feedback	Record and report	Academic/research team	Evidence of learning and adoption

Role of Farmer Education in Biopesticide Promotion

Building pest and beneficial-organism literacy

The first educational requirement is accurate identification. A farmer who cannot distinguish a damaging insect from a predator or parasitoid may treat a field unnecessarily. Education should therefore begin with photographs, preserved specimens where appropriate, field scouting and simple identification keys. Demonstrations should show common pest symptoms alongside beneficial organisms such as ladybird beetles, lacewings and parasitoids. The learning objective is not to make every farmer a taxonomist, but to improve the quality of field observations before a management decision is taken.

Teaching the IPM decision process

Biopesticide promotion is more sustainable when it is integrated into an IPM decision process rather than presented as a compulsory replacement for every chemical pesticide. Farmers need to understand prevention, crop hygiene, resistant or tolerant varieties where available, balanced crop nutrition, mechanical and physical methods, biological control, pest monitoring and economic thresholds. FAO describes IPM Farmer Field Schools as a participatory learning process that develops farmers' ecological knowledge and decision-making capacity.

Improving technical knowledge of biopesticides

Farmers may have heard of neem, Trichoderma or entomopathogenic fungi without knowing which organism controls which pest or disease. Education should cover target pest, product formulation, label directions, dose, water quality where relevant, application timing, storage, compatibility, protective equipment and waiting periods or other label requirements. Demonstrations are especially important because biopesticide performance can be sensitive to environmental and operational conditions. The message should also be clear that 'biological'

does not automatically mean 'risk-free'; all products should be used according to approved labels and applicable regulations.

Correcting misconceptions about speed and efficacy

A common adoption barrier is the expectation that every crop-protection product should produce an immediate visible kill. Education can explain that some biological control agents work through infection, parasitism, antagonism or disruption of pest development and may therefore require appropriate timing and repeated observation. Farmers should learn to evaluate efficacy using pest counts, damage levels and crop response rather than relying only on immediate visual effects.

Connecting education with economic reasoning

Adoption decisions are strongly influenced by perceived cost and risk. Farmer training should therefore include simple partial-budget comparisons: product cost, number of applications, labor, crop damage avoided, yield or quality effects and compatibility with market requirements. The purpose is not to promise that biopesticides will always be cheaper, but to help farmers compare options using crop- and pest-specific evidence.

Why Chemical Pesticide Use Can Persist Despite Alternatives

Chemical pesticide use is shaped by more than awareness. Farmers may face high pest pressure, limited access to technical advice, uncertainty about biological products, inconsistent product availability, time pressure during outbreaks, input-dealer influence and concern about crop loss. The educational strategy must therefore address the entire decision pathway. FAO notes that Farmer Field School approaches aim to build farmer capacity and awareness of risks and alternatives, while experience in IPM training has shown that farmer learning can contribute to reductions in pesticide use. In India, pesticide registration and regulation also matter. The Directorate of Plant Protection, Quarantine & Storage notes that pesticide registration is governed through the national regulatory framework, and official CIB&RC records include registered biopesticide products. Farmers should therefore be encouraged to purchase and use properly registered products and to follow label directions rather than relying on unverified homemade or commercial claims.

Table 2: Key Educational Barriers and Extension Responses

Barrier	How it affects decisions	Education response
Poor pest identification	Unnecessary or poorly targeted spraying	Field scouting, photo cards, pest/beneficial insect demonstrations
Limited knowledge of ETL/IPM	Sprays are triggered by fear rather than monitored need	Crop-specific monitoring sheets and decision exercises
Unfamiliarity with biopesticides	Low confidence and low trial rates	Small-plot demonstrations and farmer field days
Expectation of instant control	Biological options may be abandoned too early	Explain mode of action and monitoring-based evaluation
Application errors	Reduced efficacy and wasted inputs	Hands-on mixing, calibration, timing and application training
Poor product information	Use of unsuitable or unverified products	Label literacy and guidance on registered products
Limited extension access	Knowledge gaps persist after one-time meetings	NSS follow-up, KVK linkage and local farmer groups
Cost/risk concerns	Farmers prefer familiar products during outbreaks	Partial budgeting and supervised pilot demonstrations

NSS as a Platform for Farmer Education

NSS volunteers are not substitutes for plant-protection specialists. Their comparative role is community mobilization, communication, event organization, basic awareness activities, documentation and linkage with technical institutions. This distinction is essential because recommendations on pesticide products, doses and crop-specific pest management should come from qualified agricultural professionals and authorized extension channels. An NSS unit can organize a village 'Biopesticide and IPM Awareness Week' with a sequence of activities: door-to-door awareness, a village crop walk, a visual pest-identification session, a

demonstration plot, a farmer interaction meeting, a safety session and a follow-up visit. School students can participate in poster, slogan and drawing activities, while farmer groups can maintain simple pest-observation registers. The model aligns with NSS objectives of understanding community needs, using knowledge for practical solutions and mobilizing participation. The approach can also incorporate digital communication. ICAR has described ICT-enabled pest-management models that provide multimedia training, expert advisories, pest surveillance and crop-specific recommendations. Such tools can complement, rather than replace, face-to-face extension, particularly where literacy, connectivity or trust remain constraints.

Table 3: Suggested NSS Activities for a Village Biopesticide Campaign

Activity	Target group	Suggested output
Pest-identification photo exhibition	Farmers, students	Recognition of major pests and beneficial organisms
Village crop walk	Farmer groups	Field-based pest and natural-enemy observations
Biopesticide demonstration plot	Farmers	Direct observation of application and crop response
Label-reading and safety session	Spray operators/farmers	Improved label comprehension and safer handling
Farmer Field School-style meetings	Selected farmer group	Repeated observation and decision practice
Nukkad Natak/poster campaign	General community	Simple messages on unnecessary spraying and IPM
Farmer feedback meeting	Farmers + experts	Local barriers and corrective recommendations
Follow-up survey	Participating households	Evidence of knowledge and practice change

Proposed Evaluation Indicators

A major weakness of one-time awareness programmes is that participation is sometimes treated as evidence of adoption. A stronger NSS research design should separate reach, learning, behavioral change and agronomic outcomes. The following indicators can be measured before and after an intervention, and—where resources permit—against a comparison village or non-participating farmer group.

Domain	Indicator	Measurement approach
Reach	Farmers attending at least one activity	Attendance record
Knowledge	Correct identification of pests/beneficials	Pre/post identification test
IPM decision skill	Correct response to crop-scenario questions	Structured decision test
Biopesticide knowledge	Correct product-use and timing responses	Short questionnaire
Safety	Use of PPE and label compliance	Observation checklist/self-report
Chemical use	Number and type of chemical applications	Farmer spray diary; verify where possible
Biopesticide adoption	Use of an appropriate registered biopesticide within IPM	Farm record/follow-up visit
Economic outcome	Crop-protection cost and marketable yield	Partial budget and harvest record
Environmental outcome	Observed beneficial organisms and unnecessary spray events	Field scouting record

Field Challenges and Limitations

1. Biopesticide performance varies with product quality, target organism, environmental conditions and application technique; therefore education should avoid universal claims.
2. A reduction in the number of chemical sprays is not automatically evidence of better pest management. Pest pressure, yield, crop quality and economic returns must also be considered.
3. Self-reported pesticide-use data may contain recall error. Where possible, spray diaries, purchase records and field observations should be used together.

4. NSS volunteers may have limited technical training. Their activities should therefore be developed jointly with KVKs, agricultural universities, extension departments and qualified plant-protection personnel.
5. A one-time campaign may raise awareness without producing sustained behavior change. Repeated field observation, demonstration and follow-up are more appropriate for knowledge-intensive IPM.
6. Access to quality products and reliable technical advice is a structural issue that education alone cannot solve.

Strategic Recommendations and Policy Action Plan

Institutional linkage: Formalize collaboration among NSS units, KVKs, State Agricultural Universities, Gram Panchayats and agriculture departments for recurring village crop-protection education.

Demonstration-led learning: Use small, clearly documented demonstration plots comparing an IPM programme with routine farmer practice, while avoiding claims of superiority unless measured.

Farmer Field School approach: Move from lecture-based awareness to repeated crop observation, experimentation, discussion and decision-making.

Local-language materials: Develop pictorial and vernacular learning materials covering pest identification, beneficial organisms, biopesticide handling and safe pesticide practices.

Product and label literacy: Teach farmers to check registration, label directions, formulation, target pest and application instructions; discourage unverified product claims.

Youth as communication partners: Train NSS volunteers in basic IPM concepts and communication methods so they can mobilize farmers and relay expert-approved information.

Follow-up and records: Encourage simple farm diaries for pest observations, sprays, biopesticide applications, costs and crop response.

Digital extension: Use verified advisories, pest surveillance and mobile communication to support timely decisions, particularly during outbreak periods.

Conclusion

Farmer education is a central enabling factor in the transition toward safer and more sustainable crop protection. Biopesticides cannot be promoted effectively through product awareness alone. Farmers need the ecological knowledge and practical skills required to identify pests, conserve natural enemies, monitor crop conditions, interpret thresholds, select appropriate interventions and apply products correctly. The evidence and guidance reviewed here support a learning-oriented IPM approach in which biopesticides are one component of a broader decision system rather than a stand-alone substitute for all chemical pesticides.

NSS can contribute meaningfully by connecting educational institutions with rural communities through service, mobilization and repeated awareness activities. Its most appropriate contribution is to create a bridge between farmers and technical agricultural institutions. With demonstrations, local-language communication, Farmer Field School-style learning and systematic follow-up, NSS programmes can help turn awareness into informed practice. The proposed framework should be evaluated using measurable indicators of knowledge, pesticide decisions, biopesticide use, safety behavior, cost and crop outcomes rather than participation alone.

The key principle is therefore 'education for better decisions' rather than 'replacement of chemicals at any cost'. Where chemical pesticides are necessary, they should be used judiciously and according to recommendations; where preventive, biological, cultural or mechanical methods are effective, farmers should have the knowledge and confidence to use them. This balanced approach is consistent with the goals of IPM and with the NSS emphasis on linking knowledge, community service and practical action.

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