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Sustainable insect pest management in integrated farming system

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Abstract

The increasing dependence on chemical pesticides in modern agriculture has resulted in serious ecological, economic, and health-related challenges, including pest resistance, resurgence, biodiversity loss, and environmental contamination. Integrated Farming Systems (IFS), based on diversification and synergistic integration of crops, livestock, fisheries, and allied enterprises, offer a sustainable alternative for pest control. Diversification within IFS enhances ecological complexity, disrupts pest life cycles, conserves natural enemies, and reduces reliance on synthetic pesticides. This article discusses the principles and components of integrated farming systems, the ecological basis of pest suppression through diversification, and the role of crop-livestock-fish integration in sustainable pest management.

Keywords: Crop, enterprise, diversity, Eco-friendly, Insect pests

Introduction

Modern agriculture has achieved substantial gains in productivity; however, these gains have often been accompanied by ecological simplification of farming systems and an increasing dependence on synthetic chemicals for pest control. Monocropping, intensive input use, and reduced on-farm biodiversity have created favourable conditions for frequent and severe insect pest outbreaks, while simultaneously weakening natural biological control mechanisms. The indiscriminate use of pesticides has led to serious challenges such as pest resistance, resurgence, secondary pest outbreaks, contamination of soil and water resources, and adverse effects on beneficial organisms and human health. These concerns have intensified the need for sustainable, ecologically based pest management approaches in the farming sector.

Diversification-based pest control, particularly within the framework of Integrated Farming Systems (IFS), has emerged as an effective and resilient alternative to chemical-dependent pest management. Integrated farming systems involve the purposeful integration of crops, livestock, fisheries, poultry, and other allied enterprises within a single farm unit, where the by-products of one component serve as inputs for another. Such diversification enhances structural and functional complexity within agro-ecosystems, disrupts pest life cycles, reduces the dominance of single host crops, and promotes the conservation of natural enemies (Gurr *et al.,* 2017). Here, this article focuses on the role of diversification within integrated farming systems for sustainable pest control, highlighting its ecological basis and potential for enhancing productivity and resilience in modern agriculture.

Integrated Farming Systems (IFS): concept and components

IFS refer to a holistic and diversified approach to agriculture in which two or more interrelated farm enterprises are deliberately combined and managed as a single system. The central concept of IFS is the efficient utilization and recycling of resources, where the output or by-product of one component becomes the input for another, thereby reducing waste, lowering production costs, and enhancing overall farm sustainability. Unlike specialized monocropping systems, IFS emphasizes diversity, interdependence, and ecological balance to improve productivity, income stability, and environmental health.

The major components of an integrated farming system include crops (cereals, pulses, oilseeds etc.), livestock, poultry and ducks, fisheries, horticulture, agroforestry, and allied activities such as vermicomposting, biogas production, apiary and mushroom cultivation. Crop components provide food, fodder, and residues that support livestock and composting units, while livestock and poultry supply manure for soil fertility enhancement and crop nutrition. Fisheries integrated with crops, particularly in rice-based systems, utilize water resources efficiently and contribute to nutrient recycling. Agroforestry and horticultural components add structural diversity, improve microclimate, and provide additional income through vegetables, fruits, fuelwood, and timber.

Diversification as a tool for pest control

Diversification in IFS reduces pest incidence by increasing biological and structural complexity within the farming system. Unlike monocultures, diversified systems interrupt pest colonization, survival, and spread. Diversification may be spatial (intercropping, strip cropping), temporal (crop rotation, sequential cropping), or enterprise-based (crop-livestock-fish integration). Key diversification strategies include:

Crop diversification: Crop diversification helps in insect pest management by increasing plant diversity within agricultural fields, which disrupts pest host-finding, reduces the continuous availability of preferred host plants, and breaks pest life cycles (Couthouis *et al.,* 2023**)**. The presence of non-host or less preferred crops interferes with visual and chemical cues used by insects, resulting in lower colonization, feeding, and oviposition. Crop diversification also enhances the abundance and effectiveness of natural enemies by providing nectar, pollen, shelter, and alternative prey, thereby strengthening biological control and reducing pest population buildup.

Habitat diversification: Habitat diversification helps in insect pest management by increasing structural and biological complexity within and around crop fields, which enhances natural biological control and disrupts pest population growth. The inclusion of flowering plants, hedgerows, cover crops, refuges, and non-crop vegetation provides nectar, pollen, shelter, and alternative prey for predators and parasitoids, thereby improving their survival and effectiveness in suppressing insect pests (Isaacs *et al.,* 2009). Diverse habitats also interfere with pest movement and host-finding and create microclimatic conditions unfavourable for pest development. For example, planting flowering strips of marigold or coriander along vegetable fields has been shown to reduce aphid and lepidopteran pest populations by supporting ladybird beetles and parasitoid insects (Seni, 2018). Besides this, the botanicals can be used for the management of insect pests in Integrated Farming Systems (IFS) that complements diversification-based pest control and reduces dependence on synthetic insecticides. Botanicals derived from locally available plants such as neem, bael, nerium, pongamia, garlic, chilli, tobacco, and custard apple possess insecticidal, antifeedant, repellent, and growth-regulating properties that suppress pest populations while being relatively safe to natural enemies (Seni *et al.,* 2025).

Enterprise diversification: Enterprise diversification in Integrated Farming Systems (IFS) helps in insect pest management by creating a complex and biologically balanced agro-ecosystem in which crops, livestock, fisheries, poultry, and allied enterprises interact synergistically to suppress pest populations. The integration of multiple enterprises disrupts pest life cycles, reduces the dominance of single host crops, and enhances on-farm biodiversity, which supports predators, parasitoids, and insectivorous animals. Livestock and poultry help reduce weed hosts and crop residues that harbour pests, while their manure improves soil health and microbial activity, indirectly strengthening plant resistance to pests. Aquatic components and animals also directly feed on insect pests and their immature stages. For example, in a rice-duck integrated farming system, ducks feed on rice insect pests such as leaf folders and other insect larvae while also disturbing pest breeding sites, resulting in reduced pest incidence and lower pesticide use. Cow urine plays a supportive role in insect pest management within Integrated Farming Systems (IFS) as an eco-friendly, locally available input with repellent, antifeedant, and antimicrobial properties. When used alone or in fermented formulations (often mixed with botanicals such as neem, chilli, garlic, or plant extracts), cow urine acts as a deterrent to many sucking and chewing insect pests while being relatively safe to natural enemies. Its application can also enhance plant vigour by supplying micronutrients and stimulating beneficial microbial activity, indirectly increasing crop tolerance to pest damage. For example, spraying fermented cow urine-based formulations on vegetable or rice-based IFS has been reported to reduce aphids, whiteflies, leaf folders, and caterpillars while conserving predators and parasitoids. Patel *et al.,* 2017 reported the significant reduction of brinjal fruit and shoot borer, *Leucinodes orbonalis* infestation on brinjal crop after spraying of cow urine 20%.

Temporal diversification: Temporal diversification in Integrated Farming Systems

(IFS) helps in insect pest management by altering the timing and sequence of crops and farm enterprises over seasons and years, thereby breaking the continuity of host availability required for pest survival and population buildup. Practices such as crop rotation, sequential cropping, relay cropping, and staggered planting disrupt pest life cycles, reduce carryover of pest populations between seasons, and expose pests to unfavourable environmental conditions. Temporal diversification also improves soil health and supports diverse communities of natural enemies that contribute to long-term pest regulation. For example, in an IFS-based rice-pulse-oilseed rotation, pests associated with rice, such as stem borers and planthoppers, decline during the pulse and oilseed phases due to the absence of suitable hosts, resulting in lower pest incidence in subsequent rice crops.

Role of crop diversification in IFS-based pest management

Crop diversification is a cornerstone of pest control in IFS. Practices such as intercropping, mixed cropping and trap cropping reduce pest incidence by manipulating pest behaviour and enhancing biological control. Crop rotations reduce pest carryover and soil-borne insect populations, contributing to long-term pest suppression.

Intercropping: Cultivation of two or more crops together with distinct spatial arrangements. Intercropping helps reduce insect pests in diversified cropping systems by increasing plant diversity within the field, which disrupts pest host-finding behaviour and reduces the concentration of susceptible host plants (Altieri and Letourneau, 1999). Intercropping breaks pest life cycles and limits rapid population buildup by diluting food resources and altering microclimatic conditions unfavorable for pest development. Moreover, diverse intercrop arrangements provide habitats, nectar, pollen, and alternative prey for predators and parasitoids, thereby enhancing natural biological control. Intercropping tomato with coriander (*Coriandrum sativum* L.) resulted in lower incidence of the *Tuta absoluta* (Medeiros *et al.,* 2009). The cotton (*Gossypium barbadense* L.) intercropped with basil (*Ocimum basilicum* L.), had significantly lower insect pest infestation and led to a 50% reduction in abundance of the pink bollworm, *Pectinophora gossypiella* (Schader *et al.,* 2005). Likewise, when garlic was intercrop with cabbage, less infestation of DBM was observed on cabbage (Talekar *et al.,* 1985).

Mixed cropping: Growing multiple crops without a defined row pattern. The random distribution of host and non-host plants interferes with visual and chemical cues used by pests, resulting in reduced colonization, feeding, and oviposition. Additionally, the diverse plant canopy creates variable microclimatic conditions and provides food resources, shelter, and alternative prey for predators and parasitoids, thereby enhancing natural biological control. It has been observed that ladybird population (predators) positively respond to increased plant diversity (Elliott *et al.,* 2002).

Trap cropping: Trap cropping helps reduce insect pests in diversified cropping systems by strategically planting highly attractive host plants to divert pests away from the main crop, thereby preventing economic damage. Insect pests preferentially colonize the trap crop due to stronger visual and chemical cues, which concentrates their population in a limited area and reduces infestation in the primary crop. Once pests are aggregated on the trap crop, they can be effectively managed through targeted interventions such as mechanical removal, localized insecticide application, or biological control, minimizing pesticide use in the main field (Pinero and Manandhar, 2015).

Table 1: Examples of some important trap crop grown in various agro- ecosystem

Main crop	Trap crop	Pest controlled
Bengal gram	Marigold	*Helicoverpa armigera*
Groundnut	Cowpea	Leaf folder
Mustard	Cabbage	Cabbage head borer
Cotton	Marigold	*Helicoverpa armigera*
	Chick pea	*Helicoverpa armigera*
	Onion/ Garlic	*Thrips tabaci*
Tomato	Cabbage	Diamondback moth
	Marigold (2 rows planted in every 14 rows of Tomato)	Tomato fruit borer and Root Knot nematodes
Brinjal	Coriander/ Fennel (1 rows planted in every 2 rows of Brinjal)	Shoot and Fruit borer
Cabbage	Radish (Planted in every 15 rows of Cabbage)	Flea beetle
	Indian Mustard (2 rows planted in every 25 rows of cabbage)	Diamondback moth
Tabacco/ Groundnut/ tomato/ Cotton	Castor	*Spodoptera litura*
Maize	Sorghum	Shootfly and stem borer

(Source: Seni, 2018)

Crop rotation: Crop rotation helps reduce insect pests by breaking the continuity of host availability required for pest survival and multiplication. When a susceptible crop is followed by a non-host or less preferred crop, insect pests are deprived of suitable food and oviposition sites, leading to reduced survival, delayed development, and population decline. Crop rotation also disrupts pest life cycles, particularly for soil- and residue-borne insects, and reduces the carryover of pest populations between seasons. For example, rotating rice with pulses or oilseeds such as mungbean or mustard disrupts the life cycle of rice stem borers and planthoppers, leading to lower pest incidence in the subsequent rice crop (Seni, 2021). In addition, rotating crops improves soil health and supports diverse communities of natural enemies and soil organisms that contribute to pest regulation.

Role of livestock in IFS-based pest management

Livestock integration is a key component of Integrated Farming Systems (IFS) that contributes significantly to sustainable pest management through both direct and indirect ecological processes. When crops and livestock are managed together, they create a biologically complex and functionally linked agro-ecosystem that naturally suppresses insect pest populations while reducing dependence on chemical pesticides. Livestock can directly reduce insect pest populations by feeding on insects, larvae, eggs, and other pest stages. Many insect pests survive on weeds and volunteer plants during off-seasons. Grazing animals such as cattle, sheep, and goats help control weeds along field margins, bunds, and fallow lands, thereby eliminating alternate hosts and shelters for insect pests. Livestock activities such as grazing, trampling, and residue consumption disturb pest habitats and overwintering stages. By removing crop residues and stubbles that harbour insect eggs, pupae, or larvae, livestock interrupt pest life cycles. For instance, post-harvest grazing in cereal fields can reduce populations of stem borers and soil-inhabiting insects that overwinter in crop residues. Besides this, livestock manure is a valuable source of organic matter and nutrients that improve soil structure, fertility, and microbial diversity. Healthy soils support beneficial microorganisms that enhance nutrient uptake and plant vigour, making crops more tolerant to insect damage.

Role of fisheries and aquatic components

The integration of fisheries and other aquatic components into farming systems plays an important role in sustainable pest management by providing direct and indirect control of insect pests, particularly in wetland and rice-based ecosystems. Fish species introduced into crop fields, such as in rice-fish farming systems, actively feed on aquatic insect pests, mosquito larvae, insect eggs, and other immature stages, thereby directly reducing pest populations. Their continuous movement in water disturbs pest breeding and oviposition sites and limits the establishment of aquatic and semi-aquatic pests. In addition, reduced pesticide use in fish-integrated systems helps conserve predators and parasitoids, strengthening natural biological control.

Socioeconomic and environmental benefits

Diversification in IFS reduces pesticide costs, improves yield stability, and provides multiple income sources. Environmentally, it reduces pesticide residues, conserves biodiversity, improves soil and water quality, and enhances climate resilience.

Climate change and resilience

Climate change is expected to increase pest pressure and unpredictability. Diversified IFS enhances resilience by stabilizing pest-natural enemy interactions and buffering climatic extremes, making it a climate-smart pest management approach.

Future prospects

The future adoption of Integrated Farming Systems (IFS)-based pest control holds strong promise for achieving sustainable, resilient, and environmentally safe agriculture, but it requires targeted research and strategic support. Research should focus on understanding ecological interactions among crops, livestock, fisheries, and beneficial organisms, and on identifying key functional biodiversity indicators linked to pest regulation. The integration of digital tools, decision-support systems, and precision agriculture technologies can help optimize diversification designs, pest monitoring, and timely interventions. Socioeconomic research addressing farmer perceptions, labour requirements, cost-benefit analysis, and policy incentives is essential to enhance adoption.

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