

Reframing vegetable crop protection in Kashmir Valley: Integrated pest and disease management for sustainable intensification

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Abstract

Vegetables occupy a central place in Indian agriculture, contributing substantially to food and nutritional security, farm income and livelihood diversification, with Kashmir's temperate agro-climate supporting a wide range of economically important crops. However, their high perishability and susceptibility to biotic and abiotic stresses make vegetable production particularly vulnerable to losses, with fruits and vegetables recording among the highest post-harvest loss rates of any commodity group globally. This review examines the diverse complex of insect pests and plant diseases associated with major vegetable crops grown in the Kashmir valley, spanning solanaceous crops, cole crops and vegetable legumes such as French bean and pea, and highlights how foliage feeders, sap-suckers, borers, and a range of fungal, bacterial and viral pathogens have been reported to constrain yield and marketable quality across these crop groups. The paper underscores the rationale for moving away from reliance on chemical pesticides alone towards Integrated Pest and Disease Management (IPDM), an approach that combines cultural, mechanical, biological and need-based chemical interventions to achieve sustainable and eco-friendly pest suppression. Crop-wise IPM and IDM capsules are compiled and discussed for solanaceous vegetables, cole crops and legumes drawing together management approaches evaluated under Kashmir and where explicitly indicated, the wider north-western Himalayan region. The review further identifies key gaps in current management practices, including limited region-specific biorational options, insufficient monitoring and forecasting systems, and the need for climate-resilient IPDM strategies as pest dynamics shift under changing environmental conditions. Future research directions emphasizing biointensive management, molecular pest diagnostics and integration of modern tools such as remote sensing and AI-based forecasting are outlined. In conclusion, the review consolidates scattered crop-wise information into a unified IPDM framework for Kashmir's vegetable production system, with the aim of supporting evidence-based pest and disease management while contributing to sustainable vegetable production in the region.

Keywords: Biorational inputs, insect pest complex, integrated pest and disease management, Kashmir valley, vegetable crops

Introduction

Vegetables constitute an important component of Indian agriculture and horticulture and contribute substantially to food and nutritional security, farm income, employment and agricultural diversification. India is the second-largest producer of vegetables globally and according to the second advance estimates for 2024 ^[21]-25, vegetable production reached about 219.67 million tonnes (Ministry of Agriculture and Farmers Welfare, 2025). Vegetables are particularly important because of their high nutritional value and relatively short production cycles, which allow farmers to obtain frequent returns from limited land holdings. However, their high perishability and susceptibility to biological and environmental stresses make vegetable production, handling and marketing particularly vulnerable to losses. Globally, about 13.3% of food was estimated to be lost between harvest and retail in 2023, while fruits and vegetables recorded the highest loss among the major commodity groups, at about 25.4% (FAO, 2025). Reducing such losses is therefore important not only for improving food availability and farm income but also for making more

efficient use of land, water, labour and other resources invested in food production.

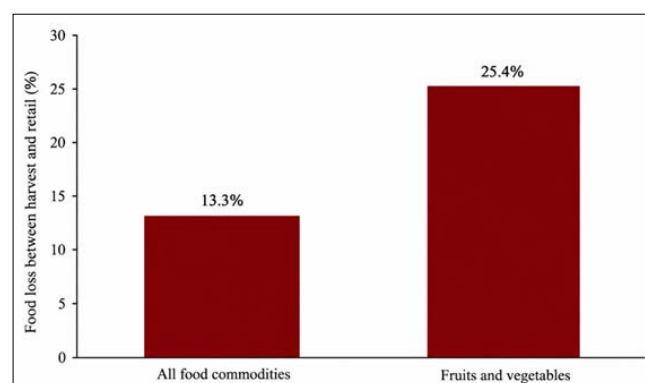


Fig 1: Food loss between harvest and retail for major food commodity groups and fruits and vegetables in 2023. Data source: FAO (2025) ^[12].

Agricultural losses arise from a combination of biological, environmental and human-related factors. Junaid and Gokce

(2024) ^[14] presented the relative contribution of different factors to agricultural losses, with insect-pests accounting for 26 per cent, weeds 23 per cent, global warming 17 per cent, anthropogenic factors 14 per cent, salinity 13 per cent and post-harvest losses 7 per cent. These factors illustrate that crop losses cannot be attributed to a single cause and may occur at different stages of production and handling. Among these factors, biotic stresses are of particular importance because insect pests, plant pathogens, mites, nematodes and weeds can directly reduce crop growth, yield and produce quality.

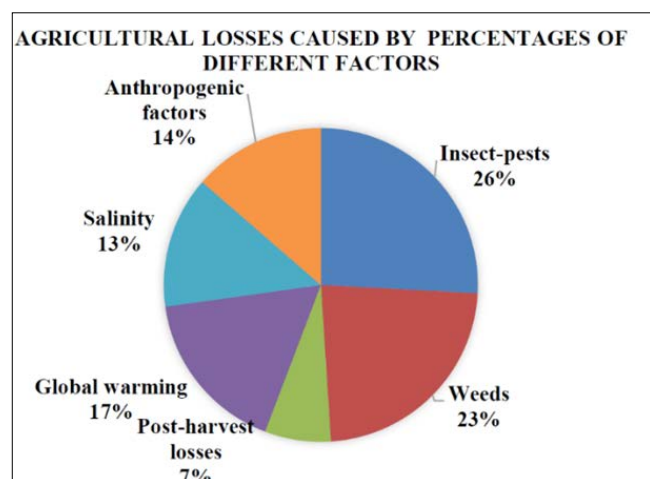


Fig 2: Reported relative contributions of different factors to agricultural losses. Source: Junaaid and Gokce (2024) ^[14].

Plant pests and diseases are estimated to reduce global crop yields by approximately 20-40 per cent annually (FAO, 2026). Their effects extend beyond direct reductions in yield, as infestation and infection can also impair product quality, reduce marketable produce and increase production costs through repeated plant protection measures. The problem is particularly important in vegetable crops because many vegetables are harvested and marketed for their fresh appearance and quality. Even moderate pest injury or disease symptoms can therefore reduce their market value. Effective management of biotic stresses is consequently an essential component of sustainable vegetable production. The Kashmir Valley represents an important temperate vegetable-growing region, where a diverse range of vegetables is cultivated under open-field as well as protected conditions. Major vegetable groups include solanaceous crops such as tomato, brinjal and chilli, cole crops such as cabbage, cauliflower and knol-khol and vegetable legumes such as pea and French bean. The relatively cool temperate conditions and diverse production systems support vegetable cultivation over a considerable part of the growing season. However, the region's diverse cropping systems and seasonal environmental conditions are also associated with the occurrence of a wide range of insect pests and plant diseases. Consequently, crop protection remains an important component of successful vegetable production in the Valley.

The insect pest complex associated with vegetables in Kashmir is diverse and includes foliage feeders, fruit and shoot borers, sap-sucking insects, leaf miners and other economically important pests. A five-year survey covering seven districts of the Kashmir Valley recorded more than 25 insect pest species belonging to 23 genera, six orders and 13

families on 23 vegetable crops (Bhat *et al.*, 2011) ^[8]. Important pests recorded from the vegetable ecosystem included cabbage butterflies, cutworms, *Spodoptera* spp., *Helicoverpa armigera*, aphids, flea beetles, leaf miners and the brinjal shoot and fruit borer. Several pests were also found to occur on more than one vegetable host, highlighting the complexity of pest management in diversified vegetable-based cropping systems in the Valley (Bhat *et al.*, 2011) ^[8].

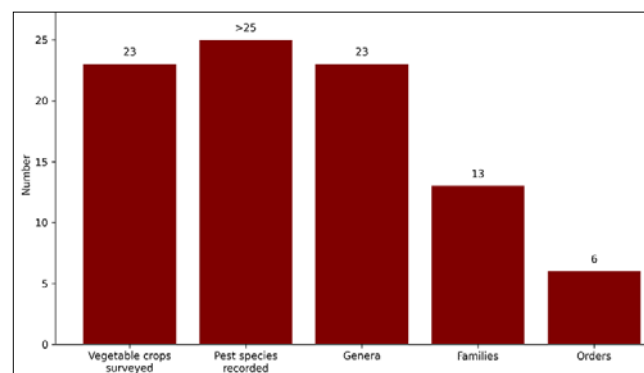


Fig 3: Diversity of insect pests associated with vegetable crops in Kashmir. Source: Bhat *et al.* (2011) ^[8].

Plant diseases are also an important component of the vegetable crop protection problem in Kashmir. Major diseases reported from the valley include *Alternaria* leaf blight of cabbage, *Septoria* leaf spot and fruit rots of tomato and fungal rots of tomato and brinjal. *Alternaria* leaf spot and early blight were also common in Budgam and Baramulla of Kashmir Valley in tomato (Bano *et al.*, 2026) ^[5]. *Alternaria* leaf spot of cabbage was recorded in Srinagar and Budgam, whereas *Septoria* leaf spot, *Alternaria* leaf spot and fruit rots have been reported as important diseases of tomato (Wani *et al.*, 2009; Anwar *et al.*, 2017) ^[2, 26]. Fungal rots caused by *Aspergillus*, *Mucor*, *Alternaria* and *Penicillium* have further been reported from tomato and brinjal in different districts of the Valley (Koka *et al.*, 2022) ^[17]. These diseases, together with wilt and other soil-borne problems, contribute substantially to the disease burden of vegetable crops and necessitate timely diagnosis and integrated management.

In addition to the occurrence of diverse pest and disease complexes, vegetable growers in Kashmir face several constraints in their management. These include the need for timely identification and monitoring of pests and diseases, dependence on chemical pesticides for rapid control, limited opportunities for preventive and biological management, the need to protect beneficial organisms and pollinators and the difficulty of maintaining effective control across different vegetable crops and production systems. Frequent harvesting of vegetables further increases the importance of pesticide selection, application timing and pre-harvest intervals. Such constraints highlight the need for management strategies that are practical under local production conditions and that can integrate preventive, biological, cultural and chemical measures.

Need for Integrated Pest and Disease Management

Chemical pesticides have long served as an important means of managing insect pests and diseases in vegetable production because of their rapid and visible effects. However, their repeated and indiscriminate use can create

several problems that compromise the sustainability of crop protection. Continuous exposure to the same or related active ingredients can favour the development of resistance in pest populations, reducing the effectiveness of recommended pesticides and increasing dependence on repeated applications or alternative chemicals (Sharma *et al.*, 2015) ^[25]. Excessive pesticide use can also disturb populations of beneficial organisms, including predators and parasitoids, which play an important role in naturally regulating pest populations. The loss of these natural enemies may contribute to pest resurgence and the emergence of secondary pest problems (Bhat *et al.*, 2020) ^[9].

The effects of intensive pesticide use extend beyond the crop itself. Pollinators, particularly honeybees visiting flowering crops, may be exposed to pesticide residues during spraying, potentially affecting pollination services and other components of pollinator health. Bioagents integrated with systemic fungicides resulted in substantially reduced disease incidence and better plant growth (Malik *et al.*, 2025) ^[19]. Concerns regarding indiscriminate pesticide use in crops have also been reported by beekeepers in the north-western Himalayan region, highlighting the wider ecological consequences of chemical-intensive crop protection (Bano *et al.*, 2023) ^[4]. Similarly, pesticide residues on harvested vegetables raise concerns regarding food safety and compliance with permissible residue limits, while pesticide drift and runoff may adversely affect soil organisms and other non-target components of the agro-ecosystem (Zhou *et al.*, 2024) ^[31]. The extensive and indiscriminate use of certain fungicides in Kashmir's apple orchards has driven the emergence of resistant pathogen populations, with a specific point mutation confirmed as the molecular basis of this resistance (Rather *et al.*, 2026) ^[24].

Instead of relying on the indiscriminate use of pesticides, there is a need to highlight economical and eco-friendly alternatives to conventional chemical control measures, such as biostimulant-based approaches that enhance plant resistance against fungal, bacterial, and viral biotic stresses (Wani *et al.*, 2024; Wani *et al.*, 2025) ^[10, 19]. A coordinated approach that integrates pest monitoring, disease surveillance, cultural practices, biological control, host resistance, sanitation and judicious pesticide use can provide more sustainable crop protection than independent and repeated applications of pesticides. Such an approach can reduce unnecessary pesticide applications while maintaining pest and disease populations below economically damaging levels. Integrated pest and disease management is therefore particularly relevant to vegetable production in Kashmir, where effective crop protection must be balanced with farmer safety, food quality, conservation of beneficial organisms and the long-term sustainability of the agro-ecosystem (Wani *et al.*, 2024) ^[10].

Integrated Pest and Disease Management of Solanaceous Vegetables

Solanaceous vegetables, particularly tomato, brinjal and chilli, are important vegetable crops grown in the Kashmir Valley. Their production is affected by several insect pests and diseases, with the pest complex varying among crops. A survey conducted across seven districts of the Kashmir Valley recorded several important insect pests associated with vegetable crops, including *Helicoverpa armigera*, *Agrotis ipsilon*, *Leucinodes orbonalis*, *Bemisia tabaci*, *Aphis gossypii*, *Myzus persicae* and *Liriomyza trifolii*. Among these, *L. orbonalis* was reported as an important pest of

brinjal, while *M. persicae*, *A. gossypii* and *H. armigera* were recorded on solanaceous crops in the Valley (Bhat *et al.*, 2011) ^[8].

Various studies from Kashmir have demonstrated the feasibility of integrated approaches for managing insect pests under both protected and open-field conditions. Mahendiran *et al.* (2015) ^[18] evaluated different IPM modules against aphids on tomato and capsicum under protected cultivation at the Central Institute of Temperate Horticulture, Srinagar, during 2011-2012 and 2012-2013. The modules combined measures such as neem cake, *Trichoderma viride*, seedling treatment, yellow sticky traps, neem seed kernel extract and insecticides. Among the modules tested, M-III, comprising soil application of neem cake at 250 kg ha⁻¹ and *T. viride* at 2.5 kg ha⁻¹, seedling dipping in imidacloprid and subsequent foliar application of imidacloprid with neem seed kernel extract, recorded the lowest aphid population. At 15 days after treatment, aphid populations were reduced to 3.33 aphids per five leaves on tomato and 5.43 aphids per five leaves on capsicum, compared with 130.56 and 101.94 aphids per five leaves, respectively, in the untreated checks (Mahendiran *et al.*, 2015) ^[18]. This study provides field-based evidence for the effectiveness of the evaluated integrated module against aphids under protected cultivation in the Kashmir valley.

Further evidence for biological control in tomato was provided by Khan and Parvaiz (2024) ^[16], who evaluated inoculative releases of *Trichogramma chilonis* against *H. armigera* and *Hippodamia variegata* against *M. persicae* in an ecologically engineered tomato ecosystem at SKUAST-K, Shalimar. The release of *T. chilonis* resulted in approximately 90% reduction of *H. armigera* population, whereas *H. variegata* resulted in 90.38% reduction of *M. persicae* population (Khan and Parvaiz, 2024) ^[16]. These findings support the inclusion of augmentative biological control and habitat management as important components of tomato IPM under Kashmir conditions.

Disease management in solanaceous vegetables has also been investigated through integrated approaches. Anwar *et al.* (2017) ^[2] evaluated different cultural, biological and chemical practices for managing major fungal diseases of tomato in Kashmir Valley. Septoria leaf spot, Alternaria leaf spot, buckeye fruit rot and Alternaria fruit rot were identified as the major diseases. Among the treatments, a combination of staking, removal of basal infected leaves, mustard straw mulching and fungicidal application recorded the lowest disease severity among the evaluated treatments. This treatment reduced Septoria leaf spot severity to 4.40 per cent and Alternaria leaf spot severity to 1.40 per cent, corresponding to disease-control values of 80.85 and 87.04 per cent, respectively. It also resulted in the lowest quantity of rotted fruits (0.65 kg plot⁻¹) and the highest yield of healthy fruits (4.65 kg plot⁻¹) (Anwar *et al.*, 2017) ^[2]. The study demonstrates the value of combining cultural practices with need-based fungicide application rather than depending on chemical control alone.

An integrated approach has also been evaluated for chilli diseases under the temperate conditions of Kashmir. In addition, root-knot nematode management has been studied in tomato and brinjal under Kashmir conditions. Askary (2020) ^[3] evaluated management options against *Meloidogyne hapla* and reported substantial reductions in root gall formation and nematode reproduction following treatment with neem-based amendments. Such studies indicate that management of solanaceous vegetables in the Valley requires consideration of insect pests, fungal diseases and soil-borne pathogens within an integrated framework.

Table 1: Integrated pest management strategies for insect pests of solanaceous vegetables in Kashmir.

Crop	Major insect pest	Scientific name	Management approach evaluated in Kashmir	Key finding	Reference
Tomato	Aphid	<i>Myzus persicae</i> / aphid complex	Neem cake + <i>Trichoderma viride</i> + seedling treatment + yellow sticky traps + NSKE + insecticide-based module	M-III recorded 3.33 aphids/5 leaves at 15 DAS compared with 130.56 aphids/5 leaves in the untreated check	Mahendiran <i>et al.</i> (2015) ^[18]
Tomato	Fruit borer	<i>Helicoverpa armigera</i>	Inoculative release of <i>Trichogramma chilonis</i> within an ecologically engineered system	Approximately 90% reduction in pest population	Khan and Parvaiz (2024) ^[16]
Tomato	Aphid	<i>Myzus persicae</i>	Inoculative release of <i>Hippodamia variegata</i> within an ecologically engineered system	90.38% reduction in aphid population	Khan and Parvaiz (2024) ^[16]
Capsicum	Aphid	Aphid complex	Neem cake + <i>T. viride</i> + seedling treatment + yellow sticky traps + NSKE + insecticide-based module	M-III recorded 5.43 aphids/5 leaves at 15 DAS compared with 101.94 aphids/5 leaves in the untreated check	Mahendiran <i>et al.</i> (2015) ^[18]
Brinjal	Shoot and fruit borer	<i>Leucinodes orbonalis</i>	Pest occurrence documented in Kashmir; Kashmir-specific published IPM experiments are limited	Important brinjal pest recorded in the Valley	Bhat <i>et al.</i> (2011) ^[8]

Table 2: Integrated disease management strategies for major diseases and soil-borne problems of solanaceous vegetables in Kashmir.

Crop	Major disease/problem	Management approach evaluated in Kashmir	Key finding	Reference
Tomato	Septoria leaf spot	Staking + removal of basal infected leaves + mustard straw mulching + mancozeb followed by carbendazim	4.40% disease severity and 80.85% disease control	Anwar <i>et al.</i> (2017) ^[2]
Tomato	Alternaria leaf spot	Staking + removal of basal infected leaves + mustard straw mulching + mancozeb followed by carbendazim	1.40% disease severity and 87.04% disease control	Anwar <i>et al.</i> (2017) ^[2]
Tomato	Buckeye fruit rot	Integrated cultural practices and fungicidal application	T15 recorded 1.27% disease severity and 0.65 kg plot ⁻¹ rotted fruits	Anwar <i>et al.</i> (2017) ^[2]
Tomato	Alternaria fruit rot	Integrated cultural practices and fungicidal application	T15 recorded 1.34% disease severity	Anwar <i>et al.</i> (2017) ^[2]
Tomato	Root-knot nematode	Neem-based and other evaluated management treatments	Neem seed powder substantially reduced gall formation and nematode reproduction	Askary (2020) ^[3]
Brinjal	Root-knot nematode	Neem-based and other evaluated management treatments	Neem seed powder substantially reduced gall formation and nematode reproduction	Askary (2020) ^[3]
Chilli	Dieback and fruit rot	Integrated nursery and field management involving biological, cultural and fungicidal measures	Integrated treatments reduced disease development under Kashmir conditions	Anwar <i>et al.</i> (2017) ^[2]

Integrated Pest and Disease Management in Cole Crops

Cole crops, particularly cabbage, cauliflower and knol-khol, form another major group of vegetables cultivated across the Kashmir Valley, occupying a large area during the summer and autumn cropping seasons. Like solanaceous vegetables, cole crops in the valley are attacked by a wide range of insect pests and diseases that vary in importance across crops and localities. The seven-district survey of Bhat *et al.* (2011) ^[8] recorded cabbage butterflies, cutworms, aphids and flea beetles among the important pests associated with vegetable crops in Kashmir, several of which are specifically associated with cole crops. The cabbage aphid, *Brevicoryne brassicae* and the diamondback moth, *Plutella xylostella*, are among the most economically important insect pests of cole crops, while the cabbage butterfly, *Pieris brassicae*, and its congener *Pieris rapae* are additional lepidopteran defoliators of regular occurrence in the Valley. Bhat *et al.* reported that cabbage and other cole crops in Kashmir are attacked by several insect pests, including the cabbage semilooper (*Thysanoplusia orichalcea* Fab.), cabbage butterfly (*Pieris brassicae* L.), diamondback moth (*Plutella xylostella* L.), mustard aphid (*Lipaphis erysimi* Kalt.) and cabbage aphid (*Brevicoryne brassicae* L.). Among diseases, *Alternaria* leaf blight has been specifically recorded on cabbage from Srinagar and Budgam districts (Wani *et al.*, 2009) ^[26], indicating that fungal foliar diseases,

in addition to insect pests, constitute an important constraint to cole crop production in Kashmir.

Biological control has received relatively greater research attention in cole crop entomology in Kashmir than in solanaceous crops, largely because of the well-documented complex of native parasitoids associated with lepidopteran pests of crucifers. Bhat and Bhagat (2008) ^[6], in a four-year field survey covering seven districts of the Valley, recorded five hymenopterous parasitoid species attacking the diamondback moth, of which three were reported for the first time from Kashmir. *Diadegma fenestrale* and *Cotesia plutellae* were found to be the most abundant and effective, causing parasitisation of up to 57.3 per cent and 29.4 per cent, respectively, indicating a strong natural regulatory potential that could be conserved and augmented within an IPM framework rather than disrupted through indiscriminate insecticide use. A related study by Bhat and Bhagat (2009) ^[7] documented natural parasitism of the cabbage white butterflies *Pieris rapae* and *Pontia daplidice* on cruciferous crops in the valley, further underlining the role of indigenous natural enemies in suppressing lepidopteran defoliators of cole crops. Building on this biocontrol potential, Mantoo and Zaki (2014) ^[20] demonstrated the efficacy of a locally isolated entomopathogenic nematode, *Heterorhabditis bacteriophora* (SKUASTK-EPN-Hr-1), against the cabbage butterfly, *Pieris brassicae*, under

Kashmir conditions, providing evidence for augmentative biological control as a viable component of cole crop IPM in the Valley.

Management of the cabbage aphid has also been investigated through botanical and chemical approaches. Ali *et al.* (2023) ^[1], working at SKUAST-Kashmir, evaluated ethanolic and aqueous extracts of *Artemisia absinthium* and *Prunus armeniaca* (apricot kernel) against *B. brassicae* and found ethanolic extract of *A. absinthium* to be the most effective, while noting that the botanicals were comparatively safer for associated natural enemies than conventional insecticides. More recently, Mir *et al.* (2026) ^[22] established the first regional baseline of organophosphate susceptibility in field populations of *B.*

brassicae from Kashmir, evaluating chlorpyrifos, dimethoate and quinalphos across eight populations. Although operational resistance was not detected, some populations showed LC₅₀ values approaching field-recommended doses and the authors emphasised continuous resistance monitoring, insecticide rotation and incorporation of non-chemical measures as essential components of sustainable aphid management in the valley. Together, these studies suggest that an integrated approach combining conservation of native parasitoids, augmentative release of entomopathogenic nematodes, judicious use of botanical aphicides and resistance-informed insecticide rotation is both feasible and necessary for cole crop pest management under Kashmir conditions.

Table 3: Integrated pest management strategies for major insect pests of cole crops in Kashmir.

Crop	Major insect pest	Scientific name	Management approach evaluated in Kashmir	Key finding	Reference
Cabbage/cole crops	Diamondback moth	<i>Plutella xylostella</i>	Field survey of natural hymenopterous parasitoids across 7 districts	<i>Diadegma fenestrale</i> and <i>Cotesia plutellae</i> caused parasitisation of 57.3% and 29.4%, respectively	Bhat and Bhagat (2008) ^[6]
Cole crops	Cabbage butterfly	<i>Pieris rapae</i> , <i>Pontia daplidice</i>	Documentation of natural parasitism on cruciferous crops	Established baseline natural parasitism levels of lepidopteran defoliators in the Valley	Bhat and Bhagat (2009) ^[7]
Cabbage	Cabbage butterfly	<i>Pieris brassicae</i>	Augmentative release of a locally isolated entomopathogenic nematode, <i>Heterorhabditis bacteriophora</i> (SKUASTK-EPN-Hr-1)	Effective biological suppression of larval populations under Kashmir conditions	Mantoo and Zaki (2014) ^[20]
Cabbage	Cabbage aphid	<i>Brevicoryne brassicae</i>	Ethanolic and aqueous extracts of <i>Artemisia absinthium</i> and <i>Prunus armeniaca</i>	Ethanolic extract of <i>A. absinthium</i> gave the highest mortality (60.25% against <i>B. brassicae</i>) while conserving natural enemies	Ali <i>et al.</i> (2023) ^[1]
Cabbage	Cabbage aphid	<i>Brevicoryne brassicae</i>	Susceptibility monitoring of 8 field populations to chlorpyrifos, dimethoate and quinalphos	First regional baseline of organophosphate susceptibility; no confirmed resistance but early tolerance flagged in some populations	Mir <i>et al.</i> (2026) ^[22]

Integrated Pest and Disease Management in Vegetable Legumes (Leguminosae/Fabaceae)

Vegetable legumes mainly include French bean (*Phaseolus vulgaris* L.) and garden pea (*Pisum sativum* L.). Both crops are cultivated extensively during the summer cropping season and contribute substantially to farm income and household nutrition. Belonging to the family Leguminosae (Fabaceae) and grown under broadly similar temperate conditions, French bean and pea share a number of common production constraints, including root rots, foliar fungal diseases (rust, leaf spot, powdery mildew, blight) and sap-sucking or pod-boring insect pests, which together necessitate an integrated approach to their management.

1. French Bean (*Phaseolus vulgaris* L.)

French bean, an important summer-season pulse-cum-vegetable crop of the Himalayan region, suffers yield losses from both fungal/bacterial diseases and insect pests. Root rot, bean rust, angular leaf spot and bacterial blight generally affect the crop and bean anthracnose is also among its common diseases under Kashmir conditions (Wani *et al.*, 2024) ^[10]. The sucking bug *Chauliops choprai* is a key insect pest (Chandrashekara *et al.*, 2022) ^[11].

Field trials in the Northwestern Himalayan region have shown that seed treatment and soil drenching with the biocontrol fungus *Trichoderma harzianum*, combined with fortified farmyard manure, substantially reduces root rot incidence and improves germination and pod yield, while soil incorporation of certain weed biomass (*Parthenium hysterophorus*, *Urtica dioica* and *Lantana camara*) has

likewise been found to suppress root rot (Chandrashekara *et al.*, 2022) ^[11]. Among fungicidal options, foliar sprays of azoxystrobin and difenoconazole have reduced angular leaf spot and rust severity by over 90 per cent, while cartap hydrochloride and botanical seed extracts have kept sucking-bug populations low; an integrated module combining seed treatment, azoxystrobin spray and cartap hydrochloride gave the lowest overall disease and pest incidence among six IPM modules tested (Chandrashekara *et al.*, 2022) ^[11]. Field surveys further show that the abundance of the major insect pests of French bean fluctuates closely with prevailing temperature, humidity and rainfall, underlining the importance of weather-based monitoring in timing interventions (Mondal *et al.*, 2018) ^[23]. For bean anthracnose specifically, *in vitro* screening using the poisoned food technique showed that among non-systemic fungicides, mancozeb 75 WP was most effective in inhibiting the mycelial growth of *Colletotrichum lindemuthianum* (75.63% mean inhibition), while carbendazim 50 WP was the most effective systemic fungicide tested (85.13% mean inhibition). A combination formulation of mancozeb (63%) and carbendazim (12%) outperformed either fungicide class applied individually, achieving the highest overall mycelial growth inhibition (89.05% mean inhibition), with efficacy increasing progressively with concentration up to 1500 ppm. Among the botanicals screened, garlic clove extract at 10 per cent concentration gave the highest inhibition (65.33%), ahead of artemisia, walnut, datura and nettle extracts (Wani *et al.*, 2024) ^[10].

Table 4: Integrated pest management strategies for insect pests of French bean in the north-western Himalayan region.

Crop	Major insect pest	Scientific name	Management approach evaluated	Key finding	Reference
French bean	Sucking bug	<i>Chauliops choprai</i>	Cartap hydrochloride and botanical seed extracts, tested under field conditions in the NW Himalayan region	Kept sucking-bug populations consistently low; effective non-disruptive option for IPM modules	Chandrashekara <i>et al.</i> (2022) ^[11]
French bean	Sucking bug + associated disease complex	<i>Chauliops choprai</i> (with root rot, rust, angular leaf spot, bacterial blight)	Six IPM modules compared, combining seed treatment, azoxystrobin foliar spray and cartap hydrochloride	The combined module gave the lowest overall disease and pest incidence among all modules tested	Chandrashekara <i>et al.</i> (2022) ^[11]
French bean	Major insect pest complex (aphid, jassid, whitefly, pod borer, etc.)	Various	Field monitoring of pest abundance against weather parameters	Pest abundance fluctuated closely with temperature, humidity and rainfall, supporting weather-based timing of interventions	Mondal <i>et al.</i> (2018) ^[23]

Table 5: Integrated disease management strategies for major diseases of French bean in the north-western Himalayan region.

Crop	Major disease/problem	Management approach evaluated	Key finding	Reference
French bean	Root rot	Seed treatment and soil drenching with <i>Trichoderma harzianum</i> + fortified farmyard manure	Substantially reduced root rot incidence; improved germination and pod yield	Chandrashekara <i>et al.</i> (2022) ^[11]
French bean	Root rot	Soil incorporation of weed biomass (<i>Parthenium hysterophorus</i> , <i>Urtica dioica</i> , <i>Lantana camara</i>)	Suppressed root rot incidence	Chandrashekara <i>et al.</i> (2022) ^[11]
French bean	Angular leaf spot, rust	Foliar sprays of azoxystrobin and difenoconazole	Reduced disease severity by over 90%	Chandrashekara <i>et al.</i> (2022) ^[11]
French bean	Bean anthracnose	<i>In vitro</i> poisoned food technique evaluating non-systemic, systemic and combination fungicides and plant extracts, against mycelial growth at multiple concentrations	Combination fungicide mancozeb (63%) + carbendazim (12%) gave the highest inhibition (89.05%); among non-systemic fungicides, mancozeb 75 WP was best (75.63%); among systemic fungicides, carbendazim 50 WP was best (85.13%); among plant extracts, garlic clove extract was best (65.33%)	Wani <i>et al.</i> (2024) ^[10]

2. Pea (*Pisum sativum* L.)

Garden pea is grown widely in Kashmir as a fresh vegetable and regionally, as a pulse crop. Its major disease complex includes powdery mildew (*Erysiphe polygoni*), rust (*Uromyces viciae-fabae*) and leaf blight (*Ascochyta pisi*), while the pod borer (*Etiella zinckenella*) and pea leaf miner (*Chromatomyia horticola*) are the principal insect pests affecting yield and pod quality. An integrated management trial conducted at the Regional Agriculture Research Station, SKUAST (Jammu & Kashmir), compared prophylactic fungicidal seed treatment, foliar fungicidal sprays and insecticidal sprays against this complex, and

found disease severity and insect damage to be lowest when fungicidal and insecticidal treatments were combined rather than applied singly (Kalha, 1992) ^[15]. The highest yield (15.88 q/ha) was obtained where seed was treated with carbendazim and thiram, combined with two foliar sprays each of mancozeb and dinocap, followed by a single insecticidal spray of endosulfan (Kalha, 1992) ^[15]. This corroborates the pattern established for French bean and the solanaceous crops discussed earlier: a combined seed treatment-foliar spray-insecticide sequence consistently outperforms single interventions against the pea pest and disease complex.

Table 6: Integrated pest management strategies for major insect pests of pea in Kashmir.

Crop	Major insect pest	Scientific name	Management approach evaluated	Key finding	Reference
Pea	Pod borer	<i>Etiella zinckenella</i>	Seed treatment (carbendazim + thiram) + foliar fungicide sprays + single insecticidal spray of endosulfan	Pod borer damage minimised; highest yield (15.88 q/ha) among treatments compared	Kalha (1992) ^[15]
Pea	Leaf miner	<i>Chromatomyia horticola</i>	Same combined module	Leaf miner damage minimised alongside disease control	

Table 7: Integrated disease management strategies for major diseases of pea in Kashmir.

Crop	Major disease/problem	Management approach evaluated	Key finding	Reference
Pea	Powdery mildew (<i>Erysiphe polygoni</i>)	Seed treatment (carbendazim + thiram) + two foliar sprays each of mancozeb and dinocap	Disease severity lowest among treatments compared	Kalha (1992) ^[15]
Pea	Rust (<i>Uromyces viciae-fabae</i>)	Same combined module	Rust severity minimised; contributed to highest overall yield	
Pea	Leaf blight (<i>Ascochyta pisi</i>)	Same combined module	Leaf blight severity minimised alongside rust and powdery mildew control	

Future Research Directions

The management of vegetable pests and diseases in the Kashmir valley has, until recently, relied largely on field-level observation, conventional bioassays and empirical evaluation of fungicide, insecticide and botanical treatments under local agro-climatic conditions. While this body of work has yielded practically useful IPM and IDM modules for several crops, the scope of research in the valley has not yet expanded to the same extent as broader trends now reshaping plant protection science elsewhere. Molecular and genomic tools, for instance, are increasingly used to characterise pathogen races, track insecticide resistance mechanisms and identify host-plant resistance genes, yet such approaches remain largely unapplied to Kashmir's vegetable pest and disease complexes and molecular resistance-monitoring work is needed across other major insect pests before resistance becomes an established field problem rather than an early warning.

Similarly, while pheromone and weather-based monitoring has begun to inform pest management decisions for a few crops such as French bean (Mondal *et al.*, 2018) [23], the valley has yet to see the application of remote-sensing and unmanned aerial vehicle (UAV) based surveillance that is increasingly used elsewhere to track pest and disease outbreaks across large cropped areas, forecast infestation risk and time interventions with greater precision. Given the fragmented landholding pattern and diverse microclimatic conditions across Kashmir's vegetable-growing districts, such tools could considerably improve the speed and accuracy with which outbreaks of pests such as the diamondback moth or diseases such as late blight are detected and managed, well before losses become severe.

There also remains substantial scope for closing specific gaps in the local literature identified through this review: dedicated field trials on cole crop diseases of global importance, particularly black rot and clubroot, for which no Kashmir-specific management data currently exist; systematic evaluation of IPM options for under-studied pests such as the brinjal shoot and fruit borer; and extension of resistance monitoring and weather-based forecasting to a wider range of vegetable crops beyond the few already studied. Bridging these gaps, alongside the gradual incorporation of molecular and remote-sensing tools into Kashmir's vegetable protection research, would considerably strengthen the evidence base for integrated pest and disease management and its extension to farmers across the Valley in the coming years.

Conclusion

The vegetable production system of the Kashmir Valley, comprising solanaceous crops, cole crops and vegetable legumes, is subject to a diverse and economically significant complex of insect pests and diseases, ranging from foliage feeders, sap-sucking insects and fruit/pod borers to fungal, bacterial and nematode pathogens. The evidence reviewed here consistently indicates that integrated approaches, combining cultural practices, biological control, botanical and biorational inputs and judicious chemical application, outperform reliance on chemical control alone across all three crop groups. In tomato and capsicum, combined botanical-biological-chemical modules and augmentative releases of parasitoids and predators achieved substantial reductions in aphid and fruit borer populations, while integrated cultural and fungicidal regimes markedly reduced

foliar and fruit rot diseases. In cole crops, indigenous parasitoid complexes and entomopathogenic nematodes demonstrated strong natural and augmentative biocontrol potential against the diamondback moth and cabbage butterfly, complemented by botanical aphicides and resistance-informed insecticide use against the cabbage aphid. In vegetable legumes, combined seed treatment-foliar spray-insecticide sequences consistently gave the lowest disease and pest incidence and the highest yields in both French bean and pea, reinforcing the same underlying principle across crop families.

The available evidence supports the continued development and field-level promotion of integrated pest and disease management strategies, tailored to the temperate agro-climatic conditions of Kashmir, as the most sustainable pathway to reducing pesticide dependence, conserving beneficial organisms and pollinators and safeguarding the yield, quality and economic returns of vegetable production in the Valley. Strengthening extension delivery of already-validated IPM/IDM modules, alongside targeted research to close the gaps identified above, will be essential to realising these benefits at the farm level.

References

1. Ali M, Ahmad T, Hussain B. Aphicidal activity of some indigenous plants extracts against cabbage aphid, *Brevicoryne brassicae* (Hemiptera: Aphididae) and mealy plum aphid, *Hyalopterus pruni* (Hemiptera: Aphididae). Archives of Phytopathology and Plant Protection, 2023, 56(11).
2. Anwar A, Bhat M, Mughal MN, Mir GH, Ambardar VK. Integrated management of major fungal diseases of tomato in Kashmir Valley, India. International Journal of Current Microbiology and Applied Sciences, 2017;6(8):2454-2458.
3. Askary TH. Management of root-knot nematode, *Meloidogyne hapla* infecting two solanaceous crops in Kashmir valley. Journal of Entomology and Zoology Studies, 2020;8(6):1914-1917.
4. Bano A, Bhat SH, Kubrevi SS, Mir SH, Saraf SA, Wani FJ, et al. Assessing constraints perceived by the beekeepers of north-western Himalayas using Garrett's ranking technique. Journal of Community Mobilization and Sustainable Development, 2023;18(4):1278-1282.
5. Bano A, Kaur R, Garg L, Rampal VK, Peshin R. Knowledge of vegetable growers in identifying pests affecting vegetable crops in Punjab and the Kashmir Valley. Journal of Community Mobilization and Sustainable Development, 2026;21(2):499-505.
6. Bhat DM, Bhagat RC. Studies on parasitoids of cabbage diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) in Kashmir Valley. Journal of Entomological Research, 2008;32(4):303-308.
7. Bhat DM, Bhagat RC. Natural parasitism of *Pieris rapae* (L.) and *Pontia daplidice* (Lepidoptera: Pieridae) on cruciferous crops in Kashmir Valley (India). American-Eurasian Journal of Agriculture and Environmental Science, 2009;5(4):590-591.
8. Bhat DM, Bhagat RC, Qureshi AA. A survey of insect pests damaging vegetable crops in Kashmir Valley (India), with some new records. Journal of Entomological Research, 2011;35(1):85-91.
9. Bhat DM, Khan SA, Ahanger FA, Sheikh MA. Diversity of aphid pests (Homoptera: Aphididae) and

- their natural bio-control agents in vegetable crop ecosystems of Jammu & Kashmir, India. *International Journal of Current Microbiology and Applied Sciences*, 2020;9(5):2529-2546.
10. Bhat MS, Hakeem SA, Malik S, Shah IM, Wani SQ, Jan SM, et al. Impact of weather parameters on population dynamics of cabbage aphid (*Brevicoryne brassicae* L.) on kale (*Brassica oleracea* var. *acephala*). *International Journal of Environment and Climate Change*, 2024;14(3):257-263.
 11. Chandrashekara C, Mishra KK, Stanley J, Subbanna ARNS, Hooda KS, Pal RS, et al. Management of diseases and insect-pests of French bean in Northwestern Indian Himalayan region using integrated approaches. *Journal of Horticultural Sciences*, 2022;17(2):448-460.
 12. FAO. SDG indicator 12.3.1: Global food losses. FAO Sustainable Development Goals Data Portal, 2025.
 13. FAO. The hidden health crisis: How plant diseases threaten global food security. FAO One Health, 2026.
 14. Junaid M, Gokce AF. Global agricultural losses and their causes. *Bulletin of Biological and Allied Sciences Research*, 2024;2024(1):66.
 15. Kalha CS. An integrated approach to the management of the major diseases and insect pests of peas in India. *Tropical Pest Management*, 1992;38(3):260-263.
 16. Khan AA, Parvaiz B. Impact of inoculative releases of *Trichogramma chilonis* for *Helicoverpa armigera* and *Hippodamia variegata* for *Myzus persicae* in ecologically engineered tomato ecosystem of Kashmir. *Indian Journal of Ecology*, 2024;51(4):891-894.
 17. Koka JA, Wani AH, Bhat MY. Incidence and severity of fungal rot of tomato and brinjal in Kashmir Valley. *Journal of Drug Delivery and Therapeutics*, 2022;12(4-S):61-67.
 18. Mahendiran G, Ganie SA, Sheikh KA, Ahmed N. Development of IPM module for commonly grown vegetables under protected cultivations in Kashmir Valley (India). *Biopesticides International*, 2015;11(1):68-72.
 19. Malik SA, Wani TA, Bhat MS, Gulzar G, Akbar A, Farooq Z, et al. Evaluating fungicides, biocontrol agents and soil amendments against *Fusarium* wilt of China aster: Towards integrated disease control. *Journal of Mycopathological Research*, 2025;63(2):377-385.
 20. Mantoo MA, Zaki F. Biological control of cabbage butterfly, *Pieris brassicae*, by a locally isolated entomopathogenic nematode, *Heterorhabditis bacteriophora* SKUASTK-EPN-Hr-1 in Kashmir. *SKUAST Journal of Research*, 2014;16:66-70.
 21. Ministry of Agriculture and Farmers Welfare. Second advance estimates of area and production of horticultural crops, 2024-25. Department of Agriculture and Farmers Welfare, Government of India, 2025.
 22. Mir IA, Rehman B, Hussain B, Ahmad T. Evaluation of insecticide susceptibility variation in different field populations of the cabbage aphid, *Brevicoryne brassicae* (Hemiptera: Aphididae), to selected organophosphate insecticides. *Journal of Biosciences*, 2026;51(3):30.
 23. Mondal A, Shankar U, Abrol DP, Kumar A, Singh AK. Incidence of major insect pests on French bean and relation to environmental variables. *Indian Journal of Entomology*, 2018;80(1):51-55.
 24. Rather MF, Bhat MA, Sakib N, Masoodi KZ, Bhat ZA, Hamid A, et al. Cytochrome b gene heteroplasmy associated with QoI fungicide resistance in *Venturia inaequalis* populations from Northwestern Himalayas. *Scientific Reports*, 2026.
 25. Sharma R, Peshin R, Shankar U, Kaul V, et al. Impact evaluation indicators of an integrated pest management program in vegetable crops in the subtropical region of Jammu and Kashmir, India. *Crop Protection*, 2015;67:191-199.
 26. Wani MA, Mir NA, Najar AG. Status of *Alternaria* leaf blight of cabbage, *Brassica oleracea* var. *capitata* L. under temperate ecology of Kashmir. *Plant Disease Research*, 2009;24(1):92.
 27. Wani SQ, Mughal NM, Bhat ZA, Bashir S, Bhat MA, Muneer K, et al. Phytomelatonin: A bioactive compound-its detection and role in growth and biotic stress management in plants. *Frontiers in Crop Improvement*, 2024;12(Special Issue-II):799-808.
 28. Wani SQ, Wani TA, Bhat MAA, Gulzar G, Muneer K, Malik S, et al. In vitro assessment of fungicides and plant extracts against common bean anthracnose incitant. *Journal of Community Mobilization and Sustainable Development*, 2024;19(3):744-750.
 29. Wani SQ, Wani TA, Gulzar G, Muneer K, Mansoor T, Malik SA, et al. Morphological characterisation of *Colletotrichum lindemuthianum* and in vitro efficacy of bioagents: Insights from dual culture method. *International Journal of Advanced Biochemistry Research*, 2024;8(5):907-913.
 30. Wani S, Wani T, Gulzar G, Ali J, Muneer K, Malik S, et al. Integrated management of anthracnose of common beans (*Phaseolus vulgaris* L.) amidst temperate conditions of Kashmir valley. *Journal of Community Mobilization and Sustainable Development*, 2025;20:386-396.
 31. Zhou W, Arcot Y, Medina RF, Bernal J, Cisneros-Zevallos L, Akbulut MES. Integrated pest management: An update on the sustainability approach to crop protection. *ACS Omega*, 2024;9(40):41130-41147.