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Review

Global threats of bean fly [*Ophiomyia* spp.] on common bean: Perspectives and limitations of management practices

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ABSTRACT

One of the most pressing challenges of our time is ensuring sustainable food systems amid environmental, socioeconomic and climatic changes. Common bean farming plays a central role in enhancing food security and alleviating malnutrition, yet its productivity is severely constrained by herbivorous pests, especially bean flies, *Ophiomyia* spp. (Diptera: Agromyzidae). Despite their potential to cause up to 100 % crop yield loss, knowledge on their distribution and management remains limited. In this study, we conducted a comprehensive review of bean fly ecology and management strategies, drawing from peer-reviewed and grey literature from major academic databases (e.g., Scopus, Web of Science, ScienceDirect) and complementary sources. Our findings highlight three key species—*Ophiomyia phaseoli* (Tryon), *Ophiomyia spencerella* (Greathead), and *Ophiomyia centrosematis* (Greathead)—each exhibiting distinct spatial and temporal distribution patterns. The species *O. phaseoli* and *O. centrosematis* are cosmopolitan, predominantly found in warm low-to mid-altitude regions, whereas *O. spencerella* is restricted to the tropical highlands of East Africa. The most significant yield losses are attributed to *O. phaseoli* and *O. spencerella*, while *O. centrosematis* occurs less frequently and has comparatively lower economic impact. Early sowing, increased precipitation, and greater varietal diversity are generally associated with lower infestation rates, whereas shortened off-season intervals and high planting densities create favourable conditions for population build-up. Synthetic pesticides remain the mainstay of bean fly control, yet they offer short-term benefits and pose considerable long-term risks to ecosystem integrity and human health. We advocate for research on sustainable bean fly management strategies that integrate ecological principles, safeguard ecosystem services, and sustain crop yields.

1. Introduction

The *Phaseolus* genus includes over 70 legume species, with the common bean (*Phaseolus vulgaris* L.) and lima bean (*Phaseolus lunatus* L.) being the most economically significant worldwide (Bitocchi et al., 2017; Garcia et al., 2021). Common beans have been a staple food for millennia, valued for their rich protein and bioactive compounds essential for human health. They contain 15–26 % protein, nearly twice that of cereal grains, and are rich in dietary fibre, saponins, phenolics, and phytosterols, which enhance gut health and overall well-being (Barampama and Simard, 1993; Broughton et al., 2003; Miles et al., 2015; Celmeli et al., 2018; Uebersax et al., 2023). Beans are also rich sources of carbohydrates, vitamins, fatty acids, and essential minerals, including selenium, iron, and zinc, all of which are crucial for dietary quality in both subsistence and industrialised communities (Celmeli et al., 2018). They are drought-tolerant and can be cultivated across a wide range of agroecological zones, from tropical lowlands to high-altitude regions in the Andes, Himalayas, and parts of Africa, where

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malnutrition is most prevalent (Broughton et al., 2003; Beebe et al., 2013; Lowe, 2021). Beans also play a critical role in soil nitrogen fixation and support a diverse community of beneficial arthropods, including pollinators, predators, and parasitoids, which contribute to natural pest regulation. As a result, they are increasingly recognised as a key lever for advancing sustainable food systems and mitigating the global risk of malnutrition, which currently affects approximately 9.2 % of the world's population (Ranganathan et al., 2018; Lurie-Luke, 2024).

Although the economic burden of biotic stress varies significantly across different agroecosystems, bean flies and bruchids have been consistently reported as the most destructive pests during field cultivation and storage, respectively (Abate and Ampofo, 1996; Singh and Schwartz, 2011; Mwanauta et al., 2015; Ssekandi et al., 2016; Karani et al., 2017). Bean flies (*Ophiomyia* spp.), also known as bean stem maggots or stem flies, are responsible for yield losses ranging from 30 to complete crop failure and are considered the most destructive pests of beans (Davies, 1998; Ojwang et al., 2009, 2021; Nkhata et al., 2019). Bean flies are thought to have originated in the Oriental and Afrotropical regions, based on the presence of native wild host plants and the occurrence of localised species (Abate, 1990). To date, it is widely distributed across Africa, Asia, Oceania [Australia and the Pacific Islands] and North America [only in the island of Hawaii] (Černý and von Tschirnhaus, 2014). The damage is primarily caused by larvae, which feed and tunnel within the host plant. After eggs are deposited on the leaf lamina or hypocotyl, the larvae hatch and mine through the mesophyll, progressing down the petiole to the stem, where pupation occurs. Symptoms of infestation typically appear approximately five weeks after sowing and include stem swelling and cracking, visible seedling mines, and the presence of immature stages within the stem (Abate, 1990, 1991). Recent studies in Malawi indicate that many farmers are unaware of the bean fly pest (Nkhata et al., 2021), while in Kenya, although farmers can recognise the symptoms, they often fail to identify the bean fly as the causal agent due to its cryptic feeding behaviour (Ojwang et al., 2009).

Management of bean flies primarily involves the use of chemical and biological pesticides, mixed cropping, breeding for systemic resistance and cultural practices. Pesticide use has increased significantly over the past decades, driven by the rising demand for food to sustain the burgeoning global population. However, in sub-Saharan Africa (SSA), many small-scale farmers, who typically own small plots of land, cannot afford pesticides or fertilisers (Schreinemachers et al., 2017; Laizer et al., 2019; Constantine et al., 2020). This limited access to agricultural inputs, coupled with water stress from reliance on rainfed cultivation, exacerbates bean fly infestations and contributes to the high levels of crop damage reported in the region (Letourneau, 1994; Ojwang et al., 2009; Ambachew et al., 2015). Moreover, the use of chemical pesticides may not be an effective control strategy for bean fly, as the larvae exhibit endophytic feeding behaviour, which shelters them within plant tissues. In some cases, pesticide application may even worsen the problem by disrupting natural pest regulation mechanisms and disturbing ecosystem balance. According to Volterra's Third Law of the Disturbance of the Averages, when pest mortality increases while an equivalent proportion of beneficial organisms is also eliminated, the resulting population dynamics favour an even greater resurgence of the pest (Ripper et al., 1949). Alternative strategies, such as the use of resistant bean varieties and cultural control practices, offer the most cost-effective and environmentally sustainable options for managing bean fly infestations. However, information on the availability and accessibility of resistant cultivars remains limited.

Although multiple bean fly species are recognised as major constraints to bean production, knowledge of their species-specific distribution and ecology remains fragmented. Before Spencer's 1973 taxonomic revision, many records were reported as *Melanagromyza* spp., creating inconsistencies across the literature. This review harmonises these records to clarify global distribution and population dynamics, with particular focus on the most damaging species on common bean. In the context of shifting climatic conditions that heighten the risks of invasions and outbreaks, we examine ecological drivers of bean fly occurrence and their implications for cultural control within integrated pest management. Given the central role of common beans in global food and nutritional security (Uebersax et al., 2023), these risks carry profound implications for resilient livelihoods. By synthesising six decades of research, we harmonise species records, disentangle infestation dynamics, and critically evaluate management efforts, highlighting persistent gaps in population ecology and control strategies. Our synthesis provides insights and conceptual frameworks that position integrated pest management as a key lever for sustainable bean fly suppression and improved food security.

2. Global research trend on bean fly

We conducted a comprehensive literature search across key databases (Scopus, Web of Science, and ScienceDirect) and complementary sources (AGRICOLA, Google Scholar, and BASE) to capture relevant literature on bean fly ecology and management. The search primarily focused on peer-reviewed journal articles, books, and book chapters. Because peer-reviewed studies on this topic were scarce, the scope was broadened to include grey literature (e.g., technical reports and academic dissertations) identified via Google Scholar and BASE. These were critically assessed on a case-by-case basis for their scientific relevance and methodological rigour and were included only when they made substantive contributions to the study. The literature search was conducted between January 4 and March 31, 2025 following the search string: ((“bean stem maggot” OR “bean fly” OR “*Ophiomyia* spp.”) AND (“distribution” OR “incidence” OR “occurrence” OR “control strategies” OR “pest management” OR “biological control” OR “chemical control”)). The resulting studies were manually imported into the Mendeley referencing manager (version 2.128.0) and Rayyan (Ouzzani et al., 2016) for deduplication and further screening. We screened all available studies on bean fly but focused on literature published between 1960 and 2025, as earlier records were largely taxonomic with limited ecological or management relevance. This period captures the earliest ecological research, six decades of progress, and the most recent advances in sustainable control. The selection of publications followed a systematic approach based on predefined criteria, including timeframe, scope, relevance to bean fly ecology and management, and accessibility of the full text. Afterwards, VOSviewer (version 1.6.20) was used to conduct a co-occurrence network analysis of keywords extracted from the reviewed literature (Fig. 1b). *Ophiomyia phaseoli* emerged as the most frequently cited species-level term, and was commonly associated with *Phaseolus vulgaris*, crop yield, and agromyzids. In contrast, *Ophiomyia spencerella* and *Ophiomyia centrosematis* appeared less frequently.

Interest in bean fly control has grown considerably over the past decades, with the majority of publications originating from major bean-producing regions in Africa (Abate and Ampofo, 1996; Abate et al., 2000; Sariah and Makundi, 2007; Ojwang et al., 2009, 2011, 2021; Mutune et al., 2016; Nkhata et al., 2019, 2021; Ngoya et al., 2024), while relatively few studies have been conducted in Asia (Talekar and Chen, 1985; Talekar and Ying Hue Lee, 1988; Talekar and Tengkano, 1993) and America (Greathead, 1975) (Fig. 2). A substantial proportion of published studies focus on the management of bean flies, with comparatively fewer focusing on their distribution and incidence. The temporal distribution of publications indicates a steady increase in research output on bean flies between 2000 and 2025 (Fig. 1a and b). Notably, a large number of research outputs have been published in low-impact journals, some of which are not indexed in peer-reviewed journal databases such as Scopus and WoS. Nonetheless, we make deliberate efforts to include these studies based on the relevance of their findings.

The study identified three key bean fly species responsible for significant yield losses in beans: *Ophiomyia phaseoli* (Tryon), *Ophiomyia spencerella* (Greathead), and *Ophiomyia centrosematis* (Greathead), each

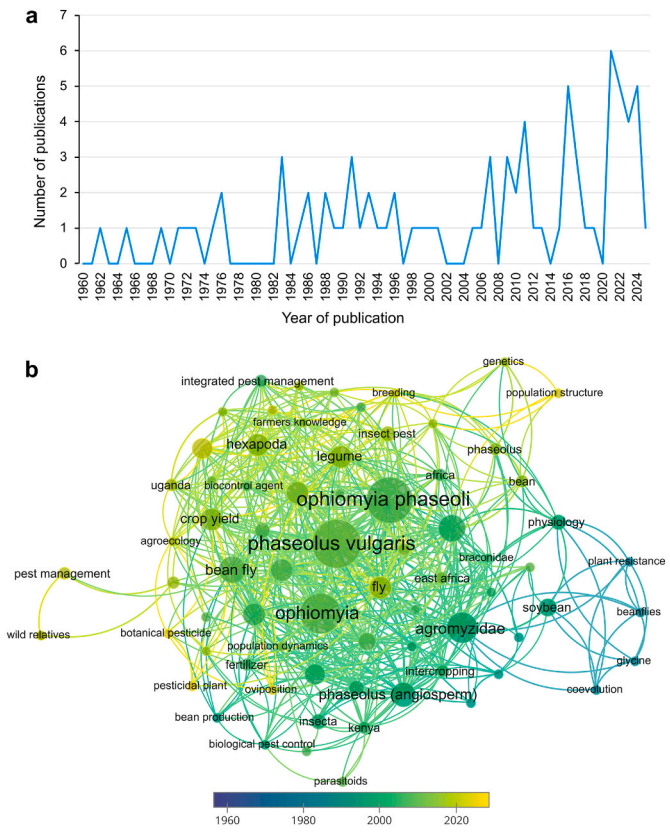


Fig. 1. Publication trends on bean fly distribution, yield loss, and management (1960–2025): (a) temporal trends in publication and (b) Keyword co-occurrence network on bean fly pests and their management. Node size reflects the frequency of keyword co-occurrence, while node colour represents the temporal evolution of research trends in bean fly ecology and control. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

exhibiting varied global distributions (Fig. 2). Among these, *O. phaseoli* is the most widespread species globally, followed by *O. centrosematis*, in contrast, *O. spencerella* has not been reported outside the continent (Fig. 2). Although several *Ophiomyia* species, including *Ophiomyia beckeri* (Hendel), *Ophiomyia dhofarensis* (Deeming), *Ophiomyia insolita* (Spencer), *Ophiomyia kilembensis* (Spencer), *Ophiomyia lantanae*, *Ophiomyia nigrimaculata* (Spencer), and *Ophiomyia ocimivora* (Spencer), are widely distributed across tropical and subtropical regions of Africa, the Americas, Australia, and Asia, none have been reported to infest common beans (Černý and von Tschirnhaus, 2014). Other stem fly species such as *Melanagromyza sojae* (Zehntner), *Melanagromyza phaseolivora* (Spencer), *Melanagromyza dolichostigma* (de Meij) and *Japanagromyza* spp. are considered minor pests of common bean, but they can cause significant yield losses in other legume crops, such as soy bean, mung bean and pea (Spencer, 1973; Gangrade and Kogan, 1980).

3. Crop infestation and yield loss

Bean fly is one of the most destructive common bean pests, with infestations capable of causing up to 100 % yield loss (Table 1). Severe yield loss has also been recorded following simultaneous infestation by other economically significant pests, including the legume pod borer (*Maruca testulalis*), bean flower thrips (*Megalurothrips* spp.), aphids (*Aphis fabae*), whiteflies (several cryptic species of *Bemisia*), cutworms (*Striacosta albicosta* and *Agrotis ipsilon*), and bean leaf beetles (*Ootheca* spp.), the bean leafhopper (*Empoasca* spp.), and bruchids (several species in the subfamily Bruchinae) (Abate and Ampofo, 1996; Alvarez et al., 2005; De Barro et al., 2011; Duff et al., 2015; Ssekandi et al., 2016; Nair et al., 2019; Ogecha et al., 2019; Krause-Sakate et al., 2020; Ferreira et al., 2022; Rodríguez-Arrieta et al., 2023). High infestations typically occur during the seedling stage, where larval feeding disrupts vascular tissues, leading to impaired nutrient and water transport and consequently stunted plant growth. The lifecycle of bean fly has been studied and widely documented in past studies (Greathead, 1969; Davies, 1998; Songa and Ampofo, 1999).

Although the three species exhibit a similar lifecycle, the oviposition site preference seems to vary across species, where *O. phaseoli* oviposits primarily on leaves of recently emerged bean plants, whereas *O. centrosematis* and *O. spencerella* prefer to oviposit in the hypocotyl (Abate and Ampofo, 1996; Lonsdale et al., 2023). The larvae emerge after 2–4 days and tunnel into the leaf petiole and stem, causing severe symptoms that may range from premature leaf fall, growth impairment, lodging, and complete crop destruction under high infestation, especially under soil infertility and drought conditions (Abate et al., 2000; Ochilo and Nyamasyo, 2011; Ssekandi et al., 2016). The punctures and mining produced by adults and larvae, respectively, also serve as a pathway for infection by opportunistic bacterial and fungal phytopathogens, which exacerbate the crop damage. The larval period lasts for about 10 days, after which they typically pupate at ground level below the stem epidermis (Abate and Ampofo, 1996; Lonsdale et al., 2023). The heavy presence of pupae at the base of the stem often results in swelling and splitting of the stem, causing rots. According to past reports, affected plants may develop adventitious roots above the pupation zone, as a strategy to compensate for the damage caused by bean fly (Davies, 1998), yet this may vary with bean crop variety and soil fertility and moisture levels.

4. Identification and diagnosis of bean fly

The adult stages of *Ophiomyia phaseoli*, *O. spencerella* and *O. centrosematis* exhibit striking morphological similarities and effective diagnosis requires meticulous examination of the aedeagal traits in the male genitalia. However, previous taxonomic studies have consistently reported distinct differences in pupal colouration and posterior spiracle morphology (Černý and von Tschirnhaus, 2014; Lonsdale, 2014). While the puparia of *O. spencerella* are primarily black with a grey ventral surface, those of *O. centrosematis* and *O. phaseoli* are predominantly brown. Furthermore, the posterior spiracle structure, especially the spacing, shape of spiracular slits, degree of cuticular pigmentation, and spiracle elevation, offers reliable diagnostic features at the pupal stage. Thus, a conscientious microscopic examination at the pupal stage is often more reliable than adult external morphologies for field and taxonomic identification. Despite extensive efforts to refine the taxonomy and identify clear synapomorphies of *Ophiomyia* spp. (Spencer, 1961; Greathead, 1969; Lonsdale, 2014; Lonsdale et al., 2023), the development of more reliable identification keys—beyond the reliance on genitalic traits and puparial morphology—remains a critical and unresolved challenge.

Although morphological identification of bean fly species is relatively well established through classical taxonomic keys (Spencer, 1961, 1973; Greathead, 1969; Waterhouse, 1998; Lonsdale et al., 2023), molecular characterisation remains comparatively limited. To date, *O. phaseoli* has been confirmed through molecular markers from populations reared on common bean in Kenya and cowpea in the Philippines, using mitochondrial cytochrome *c* oxidase subunit I (COI; accession no. EF104664), the nuclear carbamoyl-phosphate synthetase 2, aspartate transcarbamylase, and dihydroorotase (CAD; accession no. EF104837), and 28S ribosomal DNA (28S rDNA; accession no. EF104749) (Scheffer et al., 2007; Mutune et al., 2016; Liang et al., 2023). By contrast, the identification of *O. spencerella* and *O. centrosematis* has, to the best of our knowledge, relied exclusively on morphological characters, with no molecular data reported to date. Thus, molecular techniques are strongly recommended to enhance taxonomic resolution and species delimitation of *Ophiomyia* spp.

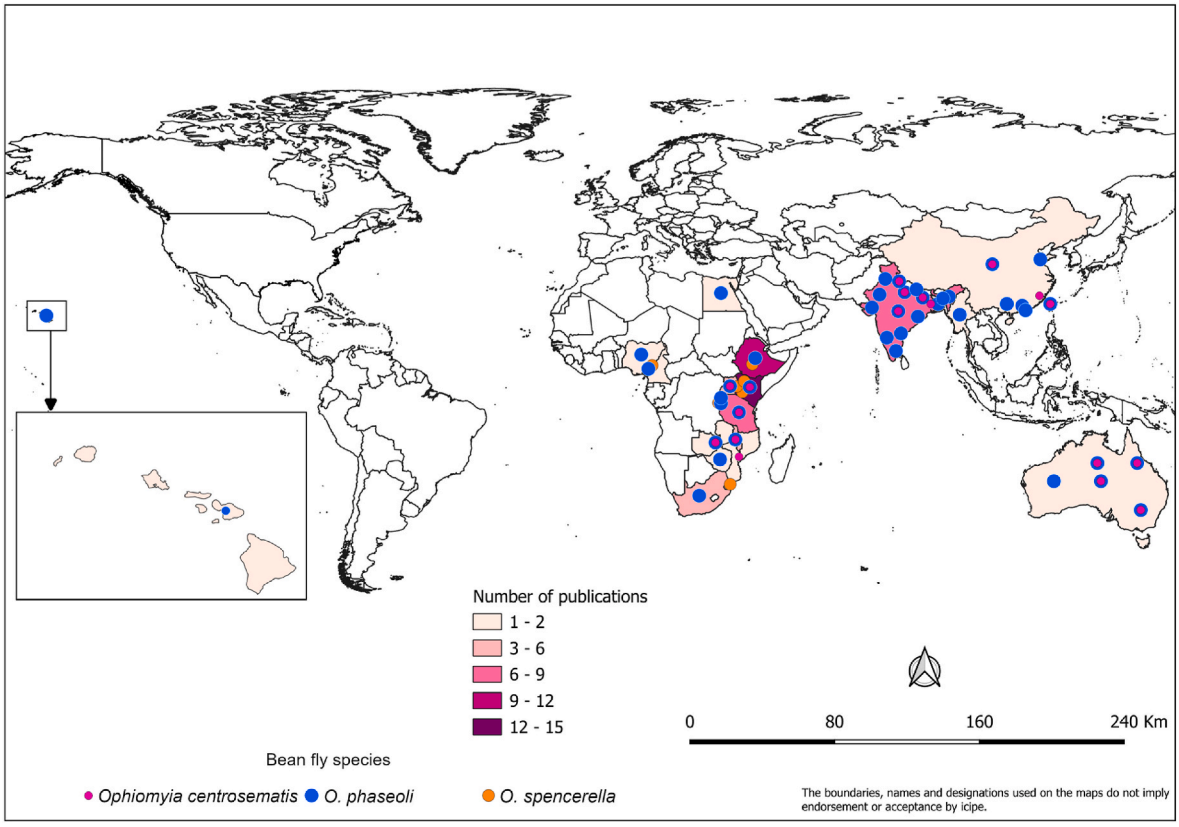


Fig. 2. Geographical distribution of the three key bean fly species as reported in published studies. Shaded regions indicate countries or regions with documented research on bean fly occurrence or management.

Table 1
Percentage yield reduction/crop loss due to bean fly infestation in different countries/locations.

Bean fly species	Host	Yield loss/Crop damage	Country/Location	Reference (s)
Ophiomyia spp.	Common bean (*P. vulgaris*)	31–40 % yield loss	Uganda	Ssekandi et al. (2016)
Ophiomyia spp.	Common bean (*P. vulgaris*)	100 % yield loss	Uganda	Greathead (1969)
O. spencerella	Common bean (*P. vulgaris*)	42–53 % crop loss	Kenya	Nderitu et al. (1990)
O. phaseoli	Common bean (*P. vulgaris*)	3–69 % yield loss	Kenya	Ojwang et al. (2010)
Ophiomyia spp.	Common bean (*P. vulgaris*)	30–100 % yield loss	Kenya	Abate and Ampofo (1996)
Ophiomyia spp.	Common bean (*P. vulgaris*)	33 % yield loss	Tanzania	Karel and Maerere (1985)
Ophiomyia spp.	Common bean (*P. vulgaris*)	17–26 % crop loss	Tanzania	Karel (1991)
O. phaseoli.	Common bean (*P. vulgaris*)	8–37 % yield loss	Ethiopia	Abate (1990)
Ophiomyia spp.	Common bean (*P. vulgaris*)	6–16 % incidence	Ethiopia	Beyene et al. (2025)
Ophiomyia spp.	Common bean (*P. vulgaris*)	90 % crop loss	Malawi	Kapeya et al. (2005)
Ophiomyia spp.	Common bean (*P. vulgaris*)	50–100 % yield loss	Zimbabwe	Abate and Ampofo (1996)
Ophiomyia spp.	Common bean (*P. vulgaris*)	10–100 % crop loss	Mozambique	Davies (1998)
Ophiomyia spp.	Soybean (*Glycine* max (L.) Merr.)	35 % yield loss	Taiwan	Talekar (1989)
O. phaseoli	French beans (*P. vulgaris* L.)	24–87 % yield loss	India	Irulandi et al. (2012)
O. phaseoli	French beans (*P. vulgaris*)	31–100 % yield loss	India	Rani and Hanumantharaya (2016)
Ophiomyia sp. and *Melanagromyza* sp.	Soybean (*Glycine* max (L.) Merr.)	85.8–90.6 % crop damage	India	(Gangrade s Kogan, 1980)
O. phaseoli	Pea (*Pisum sativum* L.)	26 % yield loss	India	Yadav et al. (2021)
O. phaseoli	Black gram (*Vigna mungo* (L.) Hepper)	5–9 % yield loss	Myanmar	Kyi et al. (2004)
O. phaseoli	Common bean (*P. vulgaris*)	81–96 % crop damage	Sri Lanka	Wickramasinghe and Fernando (1962)
O. phaseoli	Cow pea (*Vigna unguiculata* (L.) Walp)	73.9 % crop damage	Sri Lanka	Wickramasinghe and Fernando (1962)
O. phaseoli	Mung bean (*Vigna radiata* (L.) R. Wilczek)	50–100 % yield loss	Thailand	Aung et al. (2020)
O. phaseoli	Black gram (*V. mungo*)	24–37 % yield loss	Bangladesh	Prodhan et al. (2007)
O. phaseoli	Mung bean (*V. radiata*)	Minor scarring	Australia	Ingram et al. (2018)

5. Population dynamics of bean fly

Bean flies cause significant crop losses not only in the Afrotropical realm but also in the Pacific, Australasia and Oriental regions. Research indicates that although *Ophiomyia* spp. primarily infest common beans, they can also cause substantial yield losses in cowpeas, soybeans, and other leguminous plants (Abate and Ampofo, 1996). The distribution pattern and population dynamics of bean flies vary based on geographical locations and the cropping seasons of common beans. Past studies indicate that *O. phaseoli* and *O. centrosematis* are more prevalent in warm low-to mid-altitude regions, whereas *O. spencerella* is predominantly found in cooler high-altitude areas (>1000 m above sea level) (Songa and Ampofo, 1999; Ojwang et al., 2011). *Ophiomyia phaseoli* and *O. spencerella* have been associated with the highest incidence, while

O. centrosematis occurs only sporadically and in low numbers (Songa and Ampofo, 1999). Overall, high relative humidity (RH) is associated with increased bean fly infestations, whereas high precipitation tends to suppress them (Fig. 3) (Talekar and Chen, 1985; Songa and Ampofo, 1999; Nkhata et al., 2019). This pattern can be attributed to the fact that high RH enhances egg and larval development while extending the adult lifespan, leading to larger pest populations. In contrast, heavy precipitation can disrupt adult mating, oviposition, and dispersal, thereby reducing bean fly outbreaks. Although drought conditions may significantly influence bean fly outbreaks, either directly or indirectly, robust evidence is needed to elucidate infestation dynamics under changing climatic conditions.

Studies have linked various agronomic practices to bean fly infestation and population dynamics (Fig. 3). For instance, while early planting is generally associated with reduced bean fly outbreaks, yield loss in early-planted crops is higher for *O. phaseoli* compared to *O. spencerella* (Songa and Ampofo, 1999; Sariah and Makundi, 2007). Moreover, a short off-season period, typically following the short-rain cropping season, has been associated with increased bean fly populations in subsequent seasons (Nderitu et al., 1990). This may be due to the continuous presence of host plants resulting from staggered planting in previous seasons, which provides a sustained food source during the off-season. Additionally, a short off-season does not allow sufficient time for natural bean fly pupal mortality caused by desiccation or other unfavourable environmental conditions. Plant density and diversity also affect bean fly outbreaks, although studies on this relationship have yielded mixed results (Fig. 3). Karel (1991) reported that high plant populations and crop mixtures were associated with reduced bean fly infestations, likely due to higher humidity and reduced temperatures, which favour natural enemy survival. In contrast, Achiri et al. (2021) observed higher bean fly populations in densely planted fields, possibly due to the greater availability of oviposition sites, which facilitates rapid multiplication and spread (Fig. 3). The disparity in these findings may be attributed to multiple interacting factors, including natural enemy dynamics, host susceptibility, and microclimate variations, which can influence bean fly population dynamics beyond planting density alone. Soil fertility may influence bean fly attraction through bottom-up effects, ultimately increasing infestations, as observed by Letourneau (1995). However, it can also mitigate crop damage by enhancing the host plant's systemic resistance and supporting natural enemy populations, as recorded by Letourneau (1994). Therefore, a deliberate field-level assessment is necessary to examine the effects of soil fertility on tritrophic interactions and the trade-offs between bean fly attraction and suppression.

Various host plant factors play a crucial role in mitigating bean fly infestations and have become a pillar of breeding programs aimed at enhancing resistance (Fig. 3). For instance, bean varieties with high trichome densities have been linked with low bean fly infestations (Talekar and Tengkano, 1993; Ambachew et al., 2015; Ojwang et al., 2021). Additionally, various bean cultivars may deploy specific phytochemicals and volatile organic compounds (VOCs) to deter feeding by flies, further enhancing resistance. For instance, volatiles such as linalool, (syn)-2-methylbutanal oxime, (Z)-3-hexenyl acetate, (E, E)-afarnesene, (3E)-4,8-dimethyl1,3,7-nonatriene (DMNT) and (E)-2-hexen-1-al, are released by damaged bean plants to deter further infestation by agromyzid flies such as *Liriomyza* spp. (Wei et al., 2006). However, further research is needed to determine whether similar VOCs are involved in the deterrence of *Ophiomyia* spp. infestation and to quantify the extent of suppression. Studies have, however, linked certain agronomic traits—such as short internodes, small cotyledon size, reduced leaf area, and thin stems—to lower bean fly infestation (Fig. 3) (Abate, 1990; Talekar and Tengkano, 1993; Ambachew et al., 2015; Nkhata et al., 2019). These traits contribute to bean resistance against bean fly by reducing the available surface area for tunnelling, lowering food reserves, and limiting the penetration of hypocotyl and stems by newly hatched larvae.

A substantial proportion of the literature on bean fly (*Ophiomyia* spp.) population dynamics and infestation was published over two

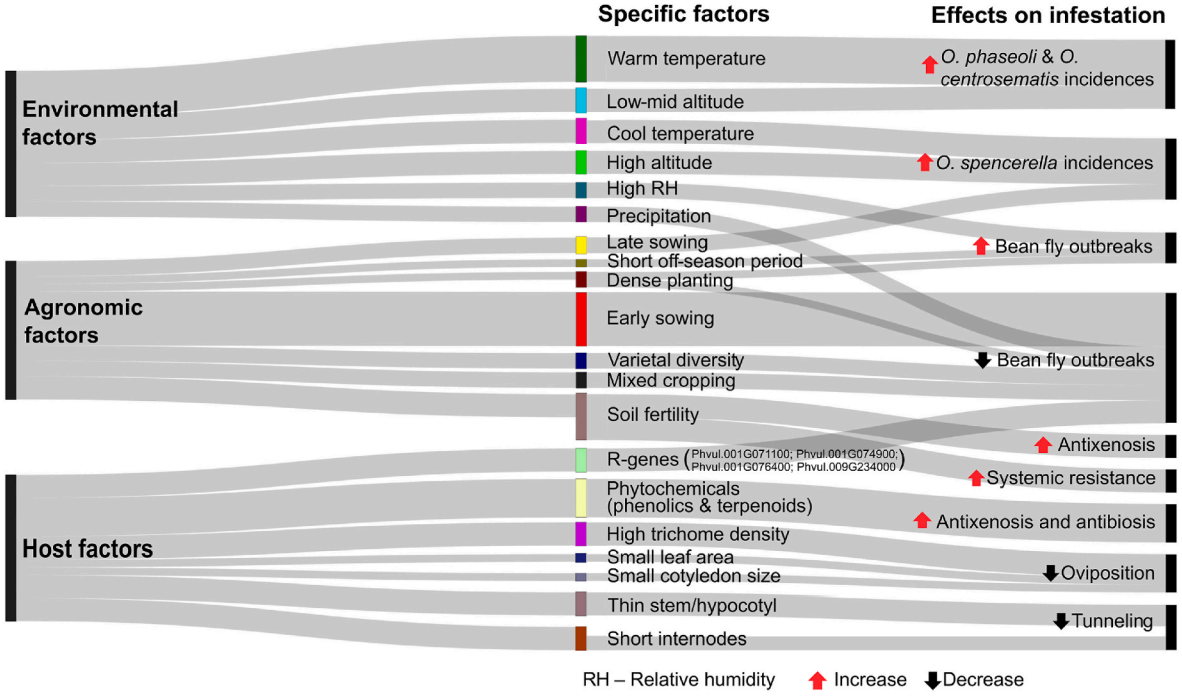


Fig. 3. Sankey diagram illustrating the relationships between environmental, agronomic, and host-related factors and bean fly outbreaks. The coloured segments at the centre represent specific factors influencing outbreaks, while the thickness of the grey lines indicates the relative importance of each factor based on the number of publications (Talekar and Chen, 1985; Karel, 1991; Letourneau, 1994, 1995; Abate and Ampofo, 1996; Davies, 1998; Songa and Ampofo, 1999; Wei et al., 2006; Ojwang et al., 2010, 2021; Ambachew et al., 2015; Ssekandi et al., 2016; Yadav et al., 2019; Cardona and Kornegay, 2019; Nkhata et al., 2019, 2021; Achiri et al., 2021).

decades ago. Given the rapidly changing climatic conditions, there is an urgent need for robust field-level research to reassess these factors. Additionally, significant gaps remain in understanding the orientation and patterns of bean fly infestation within contemporary agroecological systems. A detailed characterisation of the temporal and spatial patterns of field infestations could serve as a crucial lever for understanding bean fly biology and population dynamics, enabling timely and sustainable control strategies. While bean fly populations are likely to follow a negative binomial distribution in bean fields due to their strong preference for young plants, several interacting factors that may influence this occurrence—such as natural enemy interactions, conspecific pheromone release, field heterogeneity, edge effects, and microclimatic variations—remain largely unexplored. Furthermore, crop damage may vary across different bean fly generations, with the first-generation flies inflicting the most severe damage, as they infest plants at their most vulnerable growth stages. In contrast, damage is expected to decline with the second and third generations as the crop matures, increasing the biomass, and their stem and roots become stronger. However, this hypothesis requires further validation through conscientious field research.

6. Management of bean fly infestations

6.1. Cultural control

The management of bean fly is challenging due to the larvae's cryptic feeding behaviour and the limited understanding of their spatial and temporal population dynamics. Studies conducted in Kenya and Malawi have shown that a significant proportion of farmers are unaware of bean flies and their control strategies (Ojwang et al., 2009; Nkhata et al., 2021). This knowledge gap may stem from a combination of insect-related characteristics, such as their small size and endophytic feeding behaviour, as well as farmer-related factors, including low literacy. The effectiveness of cultural practices in managing bean fly populations has been reported with mixed findings (Table 5). Practices such as early sowing, the use of resistant bean varieties, and planting during the long rainy season have been consistently associated with reductions in bean fly incidences, highlighting their potential as effective strategies for integrated bean fly management (Talekar and Tengkano, 1993; Letourneau, 1995; Abate and Ampofo, 1996; Songa and Ampofo, 1999; Sariah and Makundi, 2007). In contrast, interventions such as mulching, fertiliser application, and crop diversification have been linked to increased bean fly populations; however, these increases did not translate into significant yield reductions (Letourneau, 1994, 1995). This outcome may be attributed to high nutrient availability, which likely enhanced the physiological resilience of bean plants against bean fly damage (Onyango et al., 2025). Moreover, fertiliser use and mixed cropping systems may have promoted the recruitment of natural enemies, thereby increasing parasitism and predation rates.

Cultivation of resistant varieties is the most sustainable and cost-effective strategy for controlling bean fly infestations. Breeding for bean fly resistance has received tangential attention, with more efforts geared towards farmers' preferred traits such as grain yield, seed colour, early maturity, and marketability (Nkhata et al., 2019, 2021). Given that most farmers lack awareness about bean fly infestations and it's control, a large fraction tend to choose varieties based on market demand trajectories as opposed to pest resistance (Bruno et al., 2018). Although previous investigations have revealed numerous phenotypic traits responsible for resistance against bean fly infestations, such as secondary metabolite production, small leaf area, short internodes, and high trichome density (leaf hairiness) (Songa and Ampofo, 1999; Ambachew et al., 2015; Cardona and Kornegay, 2019; Nkhata et al., 2021; Ojwang et al., 2021), these phenotypic traits have not been widely integrated into the commercial bean varieties. This limited incorporation is likely attributable to the physiological and genetic complexity of breeding for biotic stress resistance, which has not yet received sufficient research investment compared to abiotic stress (Beebe et al., 2014). To date, only a few conventional and hybrid varieties have been reported to possess intermediate resistance to the bean fly (Table 2). While several breeding lines have shown promising levels of resistance and tolerance (Table 3), meticulous field evaluations are still required to determine their agronomic performance, farmer acceptability, and ecological adaptability before they can be considered for commercial release. Moreover, some traits which are associated with bean fly resistance, such as small seed size (Ssekandi et al., 2016), conflict with farmers' preferred traits, such as grain yield (Nkhata et al., 2021). Compounding these challenges, bean fly outbreaks are greatly modulated by environmental factors such as temperatures, altitude, relative humidity and drought, which have made breeding outcomes across different agroecological zones inconsistent. Therefore, breeding efforts should be geared towards matching bean fly resistance traits with farmer-preferred traits to transition bean production into resilient and sustainable production systems.

6.2. Monitoring and forecasting

Effective monitoring and surveillance of bean fly populations are critical for quantifying field infestation levels, which serve as a fundamental basis for the timely implementation of control strategies. Regional coordination is crucial for effective monitoring and early detection of bean fly infestations, yet such an integrated approach remains underdeveloped in many sub-Saharan Countries. Additionally, the erratic nature of bean fly outbreaks has made their prediction challenging. Although pheromone traps have been extensively utilised for monitoring a wide range of bean pests, including cutworms, pea leaf weevils, dried bean beetles, and bean weevils (Mahrt et al., 1987; Yang et al., 2017; Reddy et al., 2018; Vuts et al., 2021), their application in bean fly surveillance remains largely undocumented. Nonetheless, pheromone traps primarily indicate the presence of adult bean fly populations in the field, but they are not reliable predictors of larval density (Mahrt et al., 1987; Reddy et al., 2018; Abang et al., 2022). As such, the integration of artificial intelligence (AI) and machine learning presents a promising approach for more accurate surveillance and monitoring of bean fly infestations. For example, data collected from pheromone traps can be integrated into cloud-based AI platforms for real-time analysis and feedback. Given that bean fly populations are highly influenced by environmental conditions, AI models trained on historical infestation levels and weather patterns could predict future outbreaks and recommend optimal intervention strategies. While there is much to learn from the successes of the neuro-fuzzy and maximum entropy algorithms used to model fall armyworm infestations and predict their ecological niches (Agboka et al., 2024), these models remain limited to a narrow scope of ecologies, and there is a need for further studies to adapt and expand their integration across diverse and complex agroecological systems.

6.3. Biological control

6.3.1. Entomopathogens

Previous studies have identified various epizootics of fungal diseases in bean flies in Kenya. Some of the common entomopathogenic fungi (EPF) species include *Metarhizium anisopliae*, *Beauveria bassiana*, *Trichoderma asperellum*, *Trichoderma atroviride* and *Hypocrea lixii* (Mutune et al., 2016). Inoculation and endophytic colonisation of bean plants with different isolates of *M. anisopliae*, *B. bassiana, Trichoderma atroviride*, and *H. lixii* have yielded 50–90 % suppression of adult fly emergence (Table 4) (Mutune et al., 2016). In addition to these, the endophytic fungi *Fusarium oxysporum* and *Gibberella moniliformis* were found to suppress feeding and infestation of other agromyzid flies such as *Liriomyza* leaf miners (*Liriomyza huidobrensis*) (Migiro et al., 2011; Akutse et al., 2013; Gathage et al., 2016; Chebet et al., 2021). The possible explanation of bean fly suppression by endophytes is through the direct pathogenicity, production of insecticidal and deterrent

Table 2
Identified bean varieties with documented intermediate resistance to bean fly infestations.

Genotype	Source	Reduction in stem damage/infestation (%)	Reduction in oviposition/no of larvae (%)	Seed type	Reference (s)
G21212 (also known as Guarcillo negro – Columbia)	ECABREN	39.6	5.6	Small black	Ojwang et al. (2021)
Jesca (also known as Kijivu/Iringa – Tanzania)	ECABREN	34.1	19.1	Other large	Ojwang et al. (2021)
AFR 701 (also known as NABE 4 – Uganda, K132 – Uganda)	ECABREN	30.2	12.9	Small black	Ojwang et al. (2021)
KAT X 56	KALRO	23.2	20.7	Red	Ojwang et al. (2021)
KATRAM 01	KALRO	23.2	14.4	Red mottled	Ojwang et al. (2021)
KAT X 69	KALRO	15.8	11.3	Red mottled	Ojwang et al. (2021)
KAT B9 (also known as Gacuma – Uganda)	KALRO	23.2	14.4	Small red	Ojwang et al. (2021)
KAT B1 (Katika – Kenya, Mbunduguru – Uganda, Goroli Njano – Tanzania)	KALRO	15.8	21.2	Other large	Ojwang et al. (2021)
KK 8 (also known as Rosecoco, Kayewa, Kabulanketi, Cranberry, Roman, Romano, Saluggia, Gadhra bean)	KALRO	28.4	9.7	Red mottled	Kiptoo et al. (2016)
Tasha	Egerton University	45.3	26.5	Red mottled	Kiptoo et al. (2016)
KK 15 – Resistant control	KALRO	20.8	15.6	Red mottled	Kiptoo et al. (2016)
Chelalang	Egerton University	68.8	19.3	Red mottled (medium to large)	Kiptoo et al. (2016)
Wairimu dwarf (also known as GLP 2 – Kenya, Uyole 96 – Tanzania, Red Wollayta – Ethiopia)	KALRO	34.0	26.5	Dark red	Kiptoo et al. (2016)
Ciankui	Egerton University	31.2	15.6	Red mottled	Kiptoo et al. (2016)
GLP 585 (also known as Red Haricot or Wairimu)	KALRO	48.1	10.8	Small-seeded red	Kiptoo et al. (2016)
Miezi mbili	KALRO	41.5	1.2	Cream or light brown mottled	Kiptoo et al. (2016)
GLP 1004 (also known as Mwezi Moja – Kenya)	KALRO	33.0	7.2	Light brown with purple speckles	Kiptoo et al. (2016)
GLP 24	KALRO	16.0	21.7	Dark red	Kiptoo et al. (2016)
GLP 1127 (also known as New Mwezi Moja)	KALRO	28.4	9.7	Dull green	Kiptoo et al. (2016)
Nambale long (also known as NABE 19, NABE 4, K132 – Uganda, Nyayo – Kenya, Maluwa – Malawi, Kabanima – Tanzania, Lyambai – Zambia, Royal Bacara – Zimbabwe)	Traditional variety	–	–	Red mottled	Ssekandi et al. (2016)
Kasirira	Traditional variety	–	–	Small black	Ssekandi et al. (2016)
Katosire	Traditional variety	–	–	Small brown	Ssekandi et al. (2016)
Kaki short (also known as NABE 13)	Traditional variety	–	–	Red mottled	Ssekandi et al. (2016)
SUA 90	Sokoine University of Agriculture	–	–	Yellowish brown	Hillocks et al. (2006)
Wanja	TARI	–	–	Red seed coat	Hillocks et al. (2006)
Mlama 127	CIAT	–	–	light brown	Hillocks et al. (2006)

GeRRI – Genetic Resources Research Institute, ECABREN – East and Central Africa Bean Research Network, KALRO Kenya Agricultural Research Institute, TARI – Tanzania Agricultural Research Institute, CIAT – International Center for Tropical Agriculture.

secondary metabolites, enhancement of plant systemic resistance and disruption of insect gut microbiota (Vega et al., 2008; Mutune et al., 2016). However, most EPFs are prone to rapid degradation due to exposure to ultraviolet radiation and dry conditions from sunlight, which limits their effectiveness in the management of field pests such as bean fly. Additionally, mass production and formulation of EPFs may be associated with high-cost implications, significantly limiting their adoption by smallholder farmers.

While there is information paucity about the use of entomopathogenic nematodes (EPNs) and bacteria (EPB) against bean fly, previous studies have documented the use of EPNs in the families Steinernematidae and Heterorhabditidae to control agromyzid flies, especially the *Liriomyza* spp. For instance, species such as *Steinernema carpocapsae* (Weiser), *Steinernema feltiae* (Filipjev), and *Heterohabditis* spp. have been documented to suppress *Liriomyza* spp. under field and greenhouse mesocosms (Liu et al., 2009; Ebrahimi et al., 2016). Unlike EPFs, most EPNs possess unique abilities to locate, infect and immobilise insect species, yet their mass production is also constrained by high-cost implications. Additionally, over 157 strains of EPBs have been described to cause epizootics in agromyzid flies, especially the *Bacillus thuringiensis* and *Serratia marcescens* (Akutse et al., 2020; Valtierra-De-luis et al., 2020). For instance, the cytolytic (Cyt) toxins (Cyt1Ba) produced by *B. thuringiensis* have been associated with the mortality of different species of insects, including the agromyzid flies (Payne et al., 1995). To date however, only one study has evaluated the use of entomopathogens (EPFs) in the management of bean flies (Mutune et al., 2016).

Table 3
Breeding lines showing potential resistance to bean fly infestation.

Breeding lines	Source	Reference (s)
G2072, G5773, ZPV 292, G2005	CIAT	(Ojwang et al., 2011; Nkhata et al., 2019)
A55, A222, A429, Sinoni, ALB 196, MW3954, SIN526, CZ114-50, SCR63, MW3917, ALB133, A344	CIAT	Nkhata et al. (2021)
GBK 047810, GBK 047866, GBK 047858, G21212, GBK 047821, GBK 036488, CIM 9314-36, IKINIMBA	CIAT	Ojwang et al. (2010)
GBK 035141, GBK 035104, GBK 032833, GBK 032803, GBK 035133, GBK 028030, GBK 032897, GBK 035069, GBK 032867, GBK 035046, GBK 032625, GBK 027810, GBK 027812, GBK 035106, GBK 028288, GBK 032824, GBK 032865, GBK 052851, GBK 035095, GBK 032626, GBK 028037, GBK 035103	GeRRI	Ojwang et al. (2021)
G22501 (Macho)	CIAT	(Hillocks et al., 2006; Ojwang et al., 2011)
CC 888 (G15430)	CIAT	Ojwang et al. (2011)
Sinon	CIAT	Hillocks et al. (2006)

CIAT – International Center for Tropical Agriculture, GeRRI – Genetic Resources Research Institute

Leveraging the functional diversity of native entomopathogens could be a game changer in our efforts to transition bean farming into a sustainable production system. Therefore, we recommend deliberate assessment of the efficacy of entomopathogens in the management of bean flies and their possible integration into bean IPM programmes.

6.3.2. Parasitoids and predators

Only a few studies have documented the use of parasitoid and predator communities in the management of *Ophiomyia* spp., most of which focus on the former (Table 4) (Greathead, 1969; Letourneau, 1994, 1995; Sariah and Makundi, 2007). Previous studies have recorded a reduction in bean fly density by up to 80 % due to parasitism by *Opius phaseoli* Fischer and *Opius importatus* Fischer (Greathead, 1975; Tengecho et al., 1988; Autrique, 1989). Yet in Letourneau (1995), the presence of *Opius phaseoli* did not affect the densities of *O. phaseoli* and *O. spencerella*. In East Africa, *Opius phaseoli* has been associated with the highest parasitism of bean fly puparia (Songa and Ampofo, 1999), while studies on the efficacy of other species, such as *Sphegigaster stepicola* (Boucek), *Sphegigaster brumeicornis* (Ferr.), and *Eucoilidea* sp., are limited (Table 4) (Jackai, 1995; Abate and Ampofo, 1996). Overall, previous observations have reported high pupal parasitism in late-planted beans, resulting in relatively high suppression of bean flies (Autrique, 1989; Davies, 1998). A possible explanation for the higher parasitism rate of the pupal stage compared to the larval stage is that, in most cases, bean flies oviposit in the hypocotyl, effectively concealing the egg and larval stages from parasitoids. Additionally, predator species such as *Coccinella undecimpunctata* L. and *Scymnus nubilus* (Mulsant) have been recorded in bean fields, yet there is no clear association between their presence and bean fly populations (Mohamed and Mahmoud, 2023). Further examination of infested plants has revealed cases of pupal predation, likely by ants (Greathead, 1969); however, additional research is needed to validate these observations. By leveraging advanced techniques such as quantitative molecular gut content analysis, we could precisely estimate the predation rates and efficiency while distinguishing active predation from mere scavenging (Peterson et al., 2018; Maggio et al., 2020).

6.4. Use of synthetic pesticides

Since their introduction, synthetic insecticides have become the default approach for mitigating yield losses caused by herbivorous pests. Previous studies have recorded a significant reduction in bean fly population following the application of organophosphates, neonicotinoids and pyrethroid pesticides with corresponding increases in bean yields (Table 5) (Ambachew et al., 2015; Muthomi et al., 2018; Mutune et al., 2018; Yadav et al., 2019; Ouma et al., 2023; Beyene et al., 2024; Ngoya et al., 2024; Onyango et al., 2025). Nevertheless, pesticide use has been linked to detrimental effects on non-target organisms, disrupting

Table 4
List of parasitoid families and species associated with the bean fly complex, including their targeted life stages and biogeographic distribution.

Family	Species	Life stages attacked	Region	References (s)
Braconidae	*Opius phaseoli* Fischer	Larvae and pupae	Afrotropical	(Greathead, 1969; Talekar and Chen, 1985; Abate, 1991; Karel, 1991; Letourneau, 1994, 1995; Davies, 1998; Songa and Ampofo, 1999; Makundi and Sariah, 2005)
	Opius importatus Fischer	Larvae and pupae	Afrotropical and Oceania	(Greathead, 1969, 1975; GBIF Secretariat, 2023)
Cynipidae	*Eucoilidea* spp.	Larvae and pupae	Cosmopolitan	(Greathead, 1969; Letourneau, 1995; Abate and Ampofo, 1996)
	Eucoilidea nitida (Benoit)	Pupae	Afrotropical	Davies (1998)
Pteromalidae	*Sphegigaster stepicola* (Boucek)	Pupae	Afrotropical and Oriental region	Abate (1991)
	Sphegigaster longicornis (Delucchi)	Pupae	Afrotropical	Abate (1991)
	Halticoptera patellana (Dalman)	Pupae	Palearctic and Oceania	(Greathead, 1975; GBIF Secretariat, 2023)
	Halticoptera circulus (Walker)	Pupae	Afrotropical, Palearctic and Nearctic	(Abate, 1991; GBIF Secretariat, 2023)
	Dinarmus basalis (Rondani)	Pupae	Afrotropical, Palearctic and Nearctic	(Agyen-Sampong, 1978; GBIF Secretariat, 2023)
	Norbanus sp.	Pupae	Afrotropical	Greathead (1969)
Eulophidae	*Chrysonotomyia formosa* (Westwood)	Pupae	Afrotropical and Nearctic	(Abate, 1991; GBIF Secretariat, 2023)
	Meruana liriomyzae (Boucek)	Pupae	Afrotropical	(Abate, 1991; GBIF Secretariat, 2023)
	Pediobius acantha (Walker)	Pupae	Afrotropical and Palearctic	(Abate, 1991; GBIF Secretariat, 2023)
	Fuderus sp.	Pupae	Afrotropical	Agyen-Sampong (1978)
	Pediobius spp.	Pupae	Afrotropical	(Greathead, 1969; Agyen-Sampong, 1978)
Eurytomidae	*Eurytoma* spp.	Pupae	Afrotropical	(Greathead, 1969; Agyen-Sampong, 1978; Abate, 1991)
	Plutarchia Girault (Subba Rao)	Larvae and Pupae	Afrotropical and Oriental regions	(Agyen-Sampong, 1978; Burikam, 1978)
Eupelmidae	*Eupelmus* spp.	Pupae	Cosmopolitan	(Greathead, 1969; Abate, 1991)

Table 5
Summary of the efficacy of cultural, biological, and chemical control strategies against bean fly.

Control strategy	Specific control approach	Target bean fly species	Key findings	Country/ Region	Reference (s)
Cultural	Mulch	*O. spencerella*	42 % decrease in bean fly puparia per plant	Malawi	Letourneau (1994)
	Fertiliser application	*O. phaseoli and O. spencerella*	2-fold increase in bean fly puparia	Malawi	Letourneau (1995)
	Early sowing	*O. phaseoli and O. spencerella*	4-6-fold reduction in bean fly puparia	Malawi	Letourneau (1995)
		O. phaseoli and O. spencerella	43.2 % reduction in *O. spencerella* puparia 12 % increase in *O. phaseoli* puparia	Tanzania	(Makundi and Sariah, 2005; Sariah and Makundi, 2007)
		O. phaseoli and O. spencerella	62 % increase in yield	Tanzania	Makundi and Sariah (2005)
	Mixed variety	*O. phaseoli and O. spencerella*	1-3-fold reduction in bean fly puparia 1-3-fold increase in parasitism	Malawi	Letourneau (1995)
	Mixed cropping	*O. phaseoli and O. spencerella*	1-3-fold increase in bean fly puparia and 3-fold increase in parasitism	Malawi	Letourneau (1995)
		O. phaseoli, O. spencerella and O. centrosematis	21–23 % reduction in ovipunctures	Tanzania	(Karel, 1991; Peter et al., 2009)
	Resistant variety	*O. phaseoli and O. spencerella*	1–72 % decrease in plant damage	Ethiopia	(Simeon et al., 2017; Wondimu, 2024)
		O. phaseoli	16–69 % decrease in plant damage/ infestation	Kenya	(Kiptoo et al., 2016; Ojwang et al., 2021)
		O. phaseoli	44-51 decrease in bean fly puparia	Taiwan	Talekar and Tengkano (1993)
	Plant population	*O. phaseoli, O. spencerella and O. centrosematis*	61 % decrease in bean fly infestations	Tanzania	Karel (1991)
	Long rains	*O. phaseoli*	10–21 % decrease in bean fly puparia 33–69 % decrease in parasitism	Kenya	Songa and Ampofo (1999)
Biological	Endophyte (*Trichoderma* spp.)	*O. phaseoli*	65–84 % decrease in bean fly puparia	Kenya	Mutune et al. (2016)
	Endophyte (*Metarhizium anisopliae*)	*O. phaseoli*	65–91 % decrease in bean fly puparia	Kenya	Mutune et al. (2016)
	Endophyte (*Beauveria bassiana*)	*O. phaseoli*	52–84 % decrease in bean fly puparia	Kenya	Mutune et al. (2016)
	Endophyte (*Hypocrea lixii*)	*O. phaseoli*	75 % decrease in bean fly puparia	Kenya	Mutune et al. (2016)
	Botanical extracts (*Tagetes minuta*)	*O. phaseoli*	18–95 % decrease in bean fly ovipunctures	Tanzania	Ngoya et al. (2024)
	Neem-based extract	*O. phaseoli*	83–90 % decrease in plant damage	India	Irulandi et al. (2012)
	Organic amendments	*O. phaseoli*	62–84 % decrease in plant damage	India	Irulandi et al. (2012)
	Parasitoid (*Opius* spp.)	*O. phaseoli*	80 % reduction in bean fly density	Burundi	Autrique (1989)
Synthetic pesticides	Dimethoate	*O. phaseoli*	94 % reduction in bean fly infestations	Ethiopia	Beyene et al. (2024)
	Alphamethrin	*O. phaseoli*	82 % reduction in bean fly infestations	Ethiopia	Beyene et al. (2024)
	lambda-cyhalothrin	*O. phaseoli*	86 % reduction in bean fly infestations	Ethiopia	Beyene et al. (2024)
	Imidacloprid	*O. phaseoli*	100 % reduction in bean fly infestations	Ethiopia	Beyene et al. (2024)
	Profenofos	*O. phaseoli*	43 % reduction in bean fly ovipunctures	Tanzania	Ngoya et al. (2024)
	Thiamethoxam	*Ophiomyia* spp.	81 % decrease in the number of larvae	Bangladesh	Rahaman and Prodhan (2007)
	Imidacloprid + lambda-cyhalothrin	*O. phaseoli*	41–44 % decrease in the infestation	Kenya	Muthomi et al. (2018)
	Seed dressing (Pencycuron) + neem extract	*O. phaseoli*	40–52 % decrease in infestation	Kenya	Muthomi et al. (2018)

survival, reproduction, and behaviour. These non-target impacts can cascade across trophic levels, thereby altering ecosystem-wide functioning (Wan et al., 2025). For example, excessive pesticide application has been shown to deplete populations of natural enemies, which in turn can trigger outbreaks of herbivorous pests such as bean flies (Saqib et al., 2020; Wan et al., 2025). Besides being associated with pesticide resistance, most synthetic insecticides are expensive and inaccessible to most smallholder bean farmers in SSA (Nkhata et al., 2021). Thus, minimising pesticide use while enhancing natural biological control is crucial and has the potential to enhance pollinator-mediated pod set and quality of common beans by up to 68 % (Otieno et al., 2020; Felipe et al., 2023). Implementing innovative integrated pest management (IPM) strategies that harness natural pest regulation mechanisms and biorationals could be transformative in advancing resilient agroecosystems and ensuring sustainable food security.

7. Conclusion and future perspectives

In summary, this study identified bean flies as the most devastating pests affecting beans, causing yield losses ranging from 60 to 100 %, particularly in the African tropics. Three key species—*O. phaseoli*, *O. spencerella*, and *O. centrosematis*—have been documented to contribute to these losses. However, their infestation levels vary depending on environmental factors such as temperature, relative humidity, and precipitation. Although *Ophiomyia* spp. are widely distributed in Africa, Asia and Oceania [i.e., Australia and the Pacific Islands], climate change may facilitate their further spread, yet the risk of invasion into other bean-growing corridors remains uncertain. Therefore, we recommend further studies to systematically assess the risk of *Ophiomyia* spp. spread and its potential impact on yield under changing climatic conditions. Additionally, bean fly outbreaks are influenced by various agronomic practices, including planting time, cropping patterns, crop density, crop variety, and soil fertility. However, much of the existing literature on their trend dates back over two decades, highlighting the need for updated information on their occurrences and effective control strategies.

Management strategies primarily rely on chemical and biological pesticides, mixed cropping, breeding for plant resistance, and other cultural practices. Although chemical pesticides are generally effective in providing short-term control of bean fly populations, they pose significant long-term risks to biodiversity, the environment, and human health. While breeding techniques offer potential solutions for managing bean fly outbreaks, modern breeding programs have primarily focused on improving yield and tolerance to abiotic stresses. Several traits associated with resistance to bean fly infestation—such as small leaf area, short internodes, dense leaf hairiness, and the production of

defensive metabolites—have been well documented. However, some resistance traits may trade off with key agronomic and market-preferred characteristics, including seed colour, grain yield, early maturity, and overall marketability. A systematic investigation is therefore required to elucidate the morphological and metabolic traits in bean cultivars that confer resistance to bean fly infestation, and to understand how these traits interact with, or potentially compromise, farmer-preferred attributes and traits that enhance biological control efficacy. Integrating these traits into breeding programs is essential for developing high-yielding, resistant bean varieties. Future research should prioritise integrated pest management strategies that combine agronomic, genetic, and ecological principles. These include optimising planting time, deploying resistant bean varieties, and applying biorational pesticides with minimal non-target effects. Equally important is enhancing ecosystem services—such as floral provisioning—to support the recruitment and persistence of natural enemies. Such integrated strategies are the primary lever for reducing bean fly outbreaks, improving bean yields, and strengthening the overall resilience and sustainability of bean production.

CRediT authorship contribution statement

Lawrence O. Onyango: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dennis Beesigamukama:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Conceptualization. **Abdullahi A. Yusuf:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Birachi Eliud Abucheli:** Writing – review & editing, Visualization, Validation. **Jean Claude Rubyogo:** Writing – review & editing, Visualization, Validation. **Shaphan Yong Chia:** Writing – review & editing, Visualization, Validation. **Arinaitwe Warren:** Writing – review & editing, Visualization, Validation. **Maria Isabel Gomez:** Writing – review & editing, Visualization, Validation. **Sunday Ekesi:** Writing – review & editing, Visualization, Validation. **Samira Mohamed:** Writing – review & editing, Visualization, Validation. **Ayuka T. Fombong:** Writing – review & editing, Visualization, Validation. **Sevgan Subramanian:** Writing – review & editing, Visualization, Validation. **Chrysantus M. Tanga:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

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