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Review

Invasive Insect Species Devastating Crop Production in Tanzania: Implications on Management and Agriculture Resilience

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ABSTRACT

Purpose: *This study synthesised evidence on the presence, pathways, and impacts of invasive insect species (IIS) on Tanzanian agriculture. With limited consolidated data despite rich biodiversity, the research fills a critical knowledge gap. Its findings aim to inform policy, enhance biosecurity, and support the development of effective IIS management strategies suited to Tanzania's diverse agro-ecological zones and farming systems.*

Research Method: *AThis study employed a systematic review methodology following PRISMA guidelines to assess the impact of invasive insect species (IIS) on Tanzania's agriculture. A comprehensive literature search in 2024 across multiple databases retrieved 2,186 records, with 134 studies ultimately selected after screening and applying inclusion criteria based on the PICOS framework. Data were drawn from peer-reviewed studies focusing on IIS affecting crops in Tanzania. Both qualitative and quantitative data were analysed to examine invasion pathways, management strategies, yield impacts, and factors influencing the spread of IIS across Tanzanian agro-ecosystems.*

Findings and Values: *Seven key pathways contribute to the spread of invasive insect species (IIS) in Tanzania: international trade, maritime shipping, air travel, illegal trade, natural dispersal, and climate change. Trade and maritime activities dominate, introducing pests like Prostephanus truncatus. Weak phytosanitary systems also allow spread via air and illicit trade. Climate and natural dispersal support species like Spodoptera frugiperda and Sipha flava. A total of 27 destructive IIS were identified: 52% Hemiptera, 22% Diptera, 15% Lepidoptera, 7% Coleoptera, and 4% Trombidiformes. Pests such as Bactrocera invadens have caused export restrictions. This marks Tanzania's first systematic review on IIS threats and management gaps.*

Keywords: *Destructive life cycles, Invasive insect species, Management strategies, Tanzania, Yield losses*

INTRODUCTION

Tanzania ranks as the 13th largest country in Africa and the 31st largest globally, encompassing an extensive area of about 947,303 square kilometres (URT 2013, NBS 2023). Since its establishment in 1964, Tanzania has witnessed a remarkable population surge, growing over sixfold from around 11.7 million in 1965 to more than 62 million in 2022 (NBS 2023). While rural habitation has historically dominated, constituting about 70% of the population, this proportion has experienced a gradual decline since at least 1967 (NBS 2023).

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Tanzania's geographical expanse encompasses a rich mix of diverse terrains, including various soils, lakes, rivers, oceans, mountains, plateaus, and a mosaic of climatic conditions ranging from equatorial, tropical, subtropical, deciduous, to semi-desert climates. This immense diversity renders Tanzania one of the world's richest countries in terms of mega-biodiversity, hosting six out of the 25 most renowned biodiversity hotspots globally (BIEP 2024). Additionally, an impressive 40% of Tanzania's land surface is allocated to forest, wildlife, and marine protected areas, underscoring the nation's commitment to conservation efforts (Busungu 2021).

Agro-ecologically, Tanzania is intricately divided, with 63 minor agro-ecological zones and 7 major agro-ecological zones identified (De Pauw 1983, Mkonda 2021). This complex topography, coupled with its diversified climate and vegetation, creates an environment conducive to various life forms, including both indigenous and invasive species. The agriculture sector forms the bedrock of Tanzania's economy, contributing an average of 29.5% to national GDP from 2013 to 2022 (NBS 2023). Furthermore, this sector plays a pivotal role in employment, absorbing approximately 77.5% of the workforce and supporting the livelihoods of over 70% of the population (URT 2013, NBS 2023). However, the intensification of agriculture has necessitated the importation of improved seeds, planting materials, and other agricultural inputs from other countries. Similarly, Tanzania relies on imports for crops such as wheat, maize, rice, oils, soybeans, and fruits due to consumption levels surpassing domestic production capacities, partly as a result of the dependence on rainfed agriculture.

This exchange of exports and imports, coupled with lax regulatory frameworks and inadequate phytosanitary control mechanisms, has heightened Tanzania's vulnerability to the infiltration of Invasive Alien Species (IAS). IAS are non-indigenous organisms that have been introduced into environments outside their natural range, often causing detrimental impacts to the new habitats they invade. These impacts include economic losses, environmental degradation, and ecological disruptions (Abass *et al.* 2013, Rudolfo *et al.* 2021, Venette & Hutchison 2021, Ndlela *et al.* 2022). Since independence, the number of IAS occurrences in Tanzania has steadily increased (Lyimo *et al.* 2009, Busungu 2021). IAS pose serious threats to agricultural biodiversity, food systems, and ecosystems, and encompass a broad range of taxa, including plants, animals, fungi, bacteria, and viruses (Rudolfo *et al.* 2021, Ndlela *et al.* 2022).

Importantly, Invasive Insect Species (IIS) are a subset within the broader category of IAS. While IAS refers to all harmful non-native organisms, IIS specifically refers to insect species that invade new ecosystems and cause harm to agriculture, biodiversity, and human livelihoods. Invasive insect species (IIS) often exhibit higher reproductive potential and tend to outcompete native species, as seen in Tanzania where the invasive fruit fly (*Bactrocera invadens*) has established dominance over other native fruit fly species (Geurt *et al.* 2014). Their impacts are often exacerbated by climate change, which expands the suitable habitat range for many insect pests, such as the Asian citrus psyllid (*Diaphorina citri*), which threatens Tanzania's citrus production (Shimwela *et al.* 2016, Jones & Brown 2018). The estimated total annual economic losses to smallholder production caused by five major invasive insect species (IIS) in Tanzania range between USD 120.4 million and 148.8 million. This represents a substantial financial burden for smallholder subsistence farmers in the country (Pratt *et al.* 2017).

Tanzania has developed the National Invasive Species Strategy and Action Plan (NISSAP) 2019–2029 as a comprehensive framework to address and manage the threats posed by invasive insect species (VPO 2019). Despite such efforts the incidence of ISS is increasing and there is currently no consolidated review or national database compiling their presence and impacts on food and cash crops. Most IIS reports have been reports of individual IIS species rather than a comprehensive review (Dunstan & Magazini 1981, Mwatawala *et al.* 2004, Mwatawala *et al.* 2007, Mwatawala *et al.* 2010, IITA 2015, Chidege *et al.* 2016, January *et al.* 2020). In the absence of a broader assessment, most control interventions have been reactive and species-specific, limiting their effectiveness (Kansiime *et al.* 2023). This fragmented approach hinders strategic planning and resource allocation for pest management, particularly when multiple IIS affect overlapping cropping systems. Therefore, a holistic understanding and compilation of the major invasive insect species is crucial for integrated and effective pest control strategies.

The aim of this research review is to identify and document key invasive insect species (IIS) currently threatening major food and cash crops in Tanzania. It also assesses their impact on crop yields and rural livelihoods, while examining the effectiveness of current control and management strategies.

MATERIALS AND METHODS

To address the increasing threat posed by invasive insect species (IIS) to Tanzania's crop production, a structured and rigorous research approach was essential. This study adopted a systematic review methodology, adhering to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines established by Moher *et al.* (2009) and modified by Page *et al.* (2021). The review was conducted in 2024, comprising four key phases: identification, screening, eligibility assessment, and final inclusion. Each phase prioritized transparency, scientific relevance, and the quality of evidence (Fig. 1).

Systematic review process

The review commenced with a targeted literature search to identify publications examining the impact of invasive insect species on crop production in Tanzania. A total of 2,186 references were retrieved from academic databases and institutional repositories including Scopus, Web of Science, PubMed, CAB Abstracts, Google Scholar, and the National Bureau of Statistics (NBS). Following the initial search, 548 duplicate records were removed, leaving 1,638 unique titles. These underwent a title screening phase, during which 927 references were excluded for lacking relevance to the topic (Fig. 1). The remaining 711 references proceeded to abstract screening. At this stage, 380 records were excluded due to misalignment with the study's geographical or thematic scope.

A total of 331 full-text articles were then assessed for eligibility, focusing on scientific rigour, relevance to Tanzanian agricultural systems, and alignment with the review's objectives. Articles were excluded if they addressed non-insect invasive species such as weeds, pathogens, or birds; if they discussed non-agricultural contexts; were not written in English; lacked data specific to Tanzania; or were unrelated to the proposed interventions. Ultimately, 134 studies met the inclusion criteria and were selected for comprehensive analysis (Fig. 1).

Resources and data sources

Multiple data sources were utilised to ensure the breadth and reliability of the review (Page *et al.* 2021). Database included Scopus, Web of Science, PubMed, CAB, ResearchGate, Google Scholar and Tanzania National bureau of statistics, conference proceedings, and institutional reports were used. Search terms included combinations such as "invasive insect species", "crop production", "Tanzania", "biological control", "chemical control", "pest outbreaks", and "agricultural biosecurity". Boolean operators were applied to narrow and refine results while maintaining thematic consistency.

Eligibility and exclusion criteria

The review was structured around the PICOS framework, which considers Population, Intervention, Comparator, Outcome, and Study Design (Table 1). The population of interest included studies that examined invasive insect species affecting crop production within Tanzania. Studies that focused on native pests or were conducted outside Tanzania were excluded. In terms of intervention, the review focused on integrated pest management approaches, including biological control, the use of biopesticides, and regulated chemical control strategies. Studies that relied solely

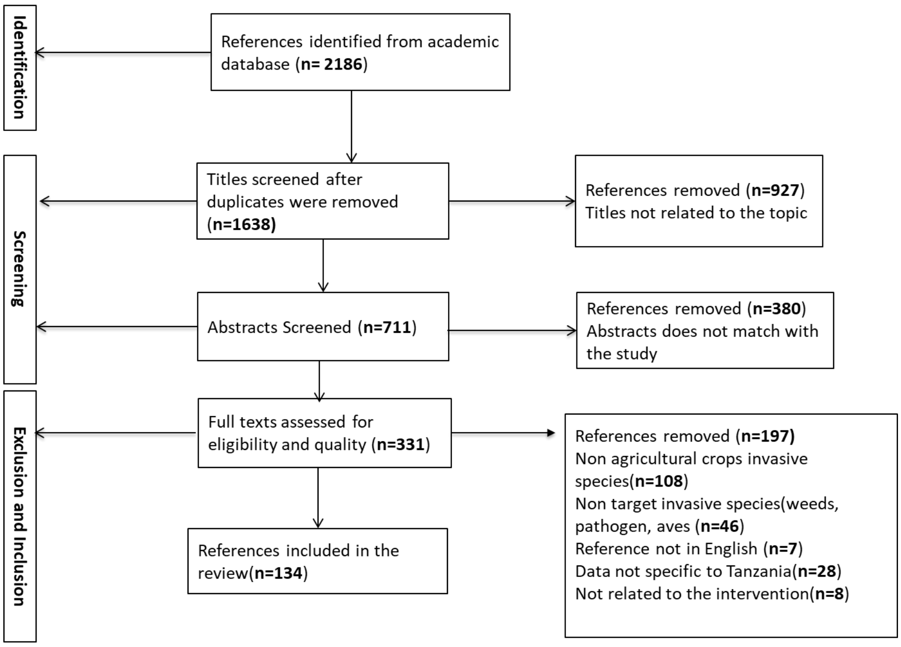

Figure 1. PRISMA flow diagram showing the process of identification, screening, eligibility, and inclusion of studies in the review of Invasive Insect Species devastating Agriculture in Tanzania.

on chemical control without environmental or economic assessments were excluded if considered irrelevant to smallholder farming systems. The comparator criteria required that eligible studies include comparisons between intervention and non-intervention scenarios. This included pre- and post-intervention data, or contrasts between traditional and modern practices. Studies that lacked a comparative element or were not aligned with Tanzanian agro-ecological conditions were excluded. For the outcome criteria, studies needed to report measurable results such as yield improvements, pest control success rates, cost-benefit analyses, or impacts on farming systems. Studies without clearly defined outcomes were excluded from the review. Finally, regarding study design, the review included empirical studies such as experimental, quasi-experimental, and observational studies, as well as systematic reviews relevant to Tanzania. Editorials, commentaries, and non-peer-reviewed sources were not included (Table 1).

Data abstraction and analysis

Included studies underwent both qualitative and quantitative assessment. Abstracts and full texts were reviewed to extract relevant information and evaluate methodological rigour. Qualitative findings were thematically coded to explore key issues such as invasion pathways, border control inefficiencies, ecological susceptibilities, and the effectiveness of pest management strategies at both regional and community levels. Quantitative data, including infestation levels, crop yield losses, economic costs of pest control, and adoption rates of interventions, were summarised descriptively. Graphs and tables were used to illustrate temporal and spatial trends. Special consideration was given to external factors such as climate variability and transboundary trade, which influence the emergence and spread of invasive pests.

RESULTS AND DISCUSSION

Invasive insect species (IIS) constitutes a growing threat to biodiversity, agriculture, and livelihoods in Tanzania, particularly in the context of global trade and climate change (Annon 1999, Lyimo *et al.* 2009, Busungu 2021). These species can spread rapidly across ecological boundaries, often outcompeting native species and causing significant economic and ecological damage. As Tanzania continues to expand its agricultural sector and participate in international trade, understanding the dynamics of IIS has become increasingly urgent (Annon 1999). The adoption of the PRISMA-guided systematic review methodology significantly enhanced the

Table 1. PICO Framework for Systematic Review on Invasive Insect Species (IIS) affecting Agriculture in Tanzania.

SN	PICOS	Inclusion Criteria	Exclusion Criteria
1	Problem	Studies on Invasive Insect Species (IIS) infesting crops in Tanzania. IIS pathways linked to global trade, climate change, or weak phytosanitary controls.	Studies on native pests only; non-agricultural ecosystems; impacts outside Tanzania; non-insect invasives.
2	Intervention	Integrated management of IIS: Biological control, Chemical control, and Biopesticides.	Chemical-only interventions without monitoring; strategies untested in smallholder contexts; invasive species promotion.
3	Comparator	High vs. low adoption regions; Pre- vs. post-intervention scenarios; Traditional vs. improved practices.	Studies without control groups; non-comparative designs; comparisons irrelevant to Tanzanian agroecosystems.
4	Outcome	Yield loss reduction, pest population suppression, cost-benefit analysis of interventions, improved food security, and farmer livelihoods.	Studies lacking quantitative or qualitative outcome data; outcomes unrelated to agricultural impact or economic/livelihood aspects.
5	Study Design	Empirical studies (experimental, quasi-experimental, observational); Reviews with synthesis of Tanzanian case studies.	Editorials, opinion pieces, grey literature without peer review; studies lacking sufficient methodological transparency.

transparency and robustness of this study's findings.

Through its structured four-phase process identification, screening, eligibility, and inclusion (Moher *et al.* 2009, Page *et al.* 2021) the methodology enabled the effective filtration of 2,186 sources down to 134 high-quality, context-relevant studies (Fig. 1).

This rigorous selection process ensured that the results presented are grounded in empirically validated and geographically appropriate data, particularly concerning the links between trade, climate, and pest dynamics. Moreover, the inclusion of both qualitative themes and quantitative trends in the analysis reflects the strength of the methodological design in capturing the multifactorial drivers and consequences of IIS invasions.

Pathways of invasive insect species introduction in Tanzania

The rising incidence of invasive insect species (IIS) in Tanzania presents a complex and growing challenge with serious consequences for agriculture, biodiversity, ecological integrity and rural livelihoods movement (Lyimo *et al.* 2009, Busungu 2021, Venette & Hutchison 2021). This situation is shaped by a convergence of globalisation, ecological vulnerability, weak phytosanitary systems, and expanding human (Brown & Smith 2019, Gomez *et al.* 2022, Venette & Hutchison 2021, Pearson *et al.* 2022). Increasing global trade has been identified as a key driver of invasive species introduction, posing growing ecological and economic challenges for Tanzanian smallholders (Levine & D'Antonio 2003). As IIS continue to spread across Tanzania's diverse agro-ecological landscapes, a deeper understanding of the mechanisms by which these species are introduced becomes crucial for effective prevention and response (Annon 1999).

International trade is the principal route by which invasive insect species enter Tanzania. The importation of agricultural commodities, timber, wooden packaging materials and ornamental plants inadvertently provides opportunities for pest species to enter new regions. A historical example is the introduction of the Larger Grain Borer (*Prostephanus truncatus*), a devastating pest of stored maize and cassava. This species was likely introduced during the 1974–1976 food crisis, when Tanzania increased grain imports from Latin America to address domestic shortages (Briggs 1979, Dunstan & Magazini 1981, Golob 1988, Hodges *et al.* 1983). Imported commodities lacking robust phytosanitary safeguards often act as vehicles for pest introduction, demonstrating the unintended ecological consequences of emergency food aid.

Maritime transport plays an equally significant role in the movement of invasive insect species (Chan & Briski 2017, Gomez *et al.* 2022). Tanzania's location along the Indian Ocean, with ports in Dar es Salaam, Tanga and Mtwara, increases its vulnerability to introductions via contaminated cargo, ballast water, or fouled ship hulls. The Oriental Fruit Fly (*Bactrocera dorsalis*, formerly *Bactrocera invadens*) exemplifies this pathway. Originating in Asia, it is thought to have reached East Africa through maritime trade routes, where it has since established itself as a major pest of mango and other tropical fruits (Shimwela *et al.* 2016, Chan & Briski 2017, Rwomushana *et al.* 2017).

The rapid expansion of air transport networks also contributes to the accidental spread of invasive species. Insects can be transported in air cargo, passenger luggage, or inside aircraft cabins. Although specific interceptions in Tanzania are scarce, global trends confirm the plausibility of this route. For example, the Mediterranean Fruit Fly (*Ceratitis capitata*), a widespread agricultural pest, has been intercepted at numerous international airports around the world (Liebhold *et al.* 2006, Tatem 2009). As air travel increases, so too does the risk of biological invasions through this pathway.

Illegal trade and unregulated movement of plants and wildlife form another major avenue for the introduction of invasive insects (Rosen & Smith 2010). These activities often evade phytosanitary checks and allow insect pests to be unknowingly transferred. The spread of the Cottony Cushion Scale (*Icerya purchasi*), a destructive citrus pest, has been associated with the informal trade in ornamental plants (Richardson *et al.* 2003, Lyimo *et al.* 2009, Rosen & Smith 2010). Tanzania's porous borders and active informal markets increase its vulnerability to pest invasions via this route.

Natural dispersal across borders is also a critical mechanism (Sisay *et al.* 2018). Many insect species possess high reproductive rates and strong mobility, enabling them to cross national boundaries unaided. The Fall Armyworm (*Spodoptera frugiperda*), native to the Americas, is a case in point. First detected in West Africa in 2016, it rapidly spread across the continent, reaching Tanzania through wind currents and natural flight from neighbouring Zambia (Topaz *et al.* 2012, Sisay *et al.* 2018, Niassy *et al.* 2021). The insect's dispersal was further supported by its exceptional capacity for reproduction and adaptability to diverse environments.

Tanzania's tourism sector, while vital for the economy, presents a further risk for pest introduction. Tourists can unintentionally carry invasive species on clothing, camping gear or vehicles, especially when moving between protected areas and rural landscapes. Over sixty invasive species have been recorded in Tanzanian national parks, reflecting a link between recreational activities and ecological disturbance (Cooper *et al.* 2003, Anderson *et al.* 2015, Makunga & Gobolo 2020, TANAPA 2020). The spread of the Spiralling Whitefly (*Aleurodicus dispersus*) is suspected to have been facilitated by such forms of unintentional human-assisted transport.

Climate change is intensifying the establishment and spread of invasive insect species in Tanzania. Rising temperatures, altered rainfall patterns and increased climate variability have expanded the range and breeding seasons of many pests. The Yellow Sugarcane Aphid (*Sipha flava*) provides an illustrative example, as its geographic range has expanded under shifting climate conditions in East Africa (Visser & Both 2005, Smith *et al.* 2012, January *et al.* 2020, White *et al.* 2020). Warmer climates and prolonged growing seasons allow multiple generations per year, amplifying pest pressure on both cultivated and wild vegetation.

The issue of invasive species management in Tanzania is significantly undermined by institutional weaknesses, despite the existence of legal and regulatory frameworks for quarantine and plant protection. Limited resources, inadequate infrastructure, and fragmented coordination often result in delayed detection and response, with invasive species typically identified only after establishment. This reflects systemic failures such as the absence of early warning systems, insufficient border surveillance, and low public awareness. Tanzania's ecological richness, while advantageous for biodiversity and agriculture, paradoxically increases vulnerability to biological invasions due to the multitude of niches available for invasive pests to exploit. In comparison, García *et al.* (2017) emphasize the critical importance of Early Detection and Rapid Response (EDRR) strategies in enhancing the efficacy of invasive species management (Levine & D'Antonio 2003, Venette & Hutchison 2021). Their study illustrates how proactive surveillance, inter-agency coordination, and investment in rapid response infrastructure can prevent the establishment and spread of invasive species. Whereas Tanzania's response is largely reactive, the EDRR model presents a more preventative and cost-effective framework that could inform future policy reforms. Integrating such strategies into Tanzania's system could help mitigate the delays and inefficiencies currently experienced, ultimately improving the country's capacity to manage invasive threats effectively (García *et al.* 2017, Gomez *et al.* 2022).

Status of insect invasive species in Tanzania

The proliferation of invasive insect species in Tanzania presents a mounting challenge for agricultural productivity, food security, and biodiversity conservation. Currently, 27 invasive insect species have been identified across the country, representing various taxonomic orders, most notably Hemiptera, Diptera, Lepidoptera, Coleoptera, and Trombidiformes. Among these, Hemiptera is the most dominant group, accounting for 14 species, followed by Diptera with six species, Lepidoptera with four, Coleoptera with two, and one species from the Trombidiformes order (CABI 1971, Herren & Neuenschwander 2001, Mwatawala *et al.* 2004, Mwatawala *et al.* 2006, Mwatawala *et al.* 2007, Mwatawala *et al.* 2010). These invasive species originate from a broad range of global regions, including Central and South America, Asia, Europe, and Australia, highlighting the international nature of biological invasions and their pathways into Tanzania. Studies from India—a country that shares oceanic proximity and strong trade links with Tanzania—reveal patterns relevant to our context. These studies indicate a notable prevalence of Hemiptera as the most abundant group of invasive insect species. This correspondence suggests similar ecological vulnerabilities in Tanzania due to comparable environmental and trade dynamics (Daniel *et al.* 2020).

The presence and establishment of these insects carry significant ecological and economic implications. Agriculturally, many of these invasive species attack key crops, inflicting damage through direct feeding and by serving as vectors for plant diseases. For instance, *Spodoptera frugiperda* (fall armyworm), originally from the Americas, has been a major pest of maize and sorghum since its detection in 2017, while *Tuta absoluta* (tomato leaf miner), introduced from Peru, has devastated tomato yields (Chidege *et al.* 2016, Sisay *et al.* 2018). The economic consequences are severe, with infestations reducing both the quantity and quality of agricultural outputs. As a result, farmers face diminished market prices and

Table 2. Pathways of Invasive Insect Species Introduction in Tanzania.

SN	Pathway category	Mechanism of Introduction	Representative Insect	Reference
1	International Trade	Accidental hitchhiking on imported goods (agricultural products, timber, ornamental plants)	*Prostephanus truncatus*	Briggs (1979), Dunstan & Magazini (1981), Golob (1988), Hodges *et al.* (1983)
2	Shipping & Maritime	Transport via ballast water or hull fouling; ports as entry points	*Bactrocera invadens*	Shimwela *et al.* (2016), Chan & Briski (2017), Rwomushana *et al.* (2017)
3	Air Travel	Hitchhiking on aircraft, luggage, or air cargo	*Ceratitis capitata*	Liebhold *et al.* (2006), Tatem (2009)
4	Illegal Trade	Trafficking of infested plants or animals; accidental releases	*Icerya purchasi*	Richardson *et al.* (2003), Lyimo *et al.* (2009), Rosen & Smith (2010)
5	Natural Dispersal	Wind, water currents, or active flight across borders	*Spodoptera frugiperda*	Topaz *et al.* (2012), Sisay *et al.* (2018), Niassy *et al.* (2021)
6	Tourism & Recreation	Contamination via clothing, gear, or recreational equipment	*Aleurodicus dispersus*	Anderson *et al.* (2015), Makunga & Gobolo (2020), TANAPA (2020)
7	Climate Change	Expansion of suitable habitats due to warming; altered species interactions	*Sipha flava*	Visser & Both (2005), Smith *et al.* (2012), January *et al.* (2020), White *et al.* (2020)

incomes. A notable example is the larger grain borer, *Prostephanus truncatus*, which infests stored maize and causes considerable post-harvest losses (Dunstan & Magazini 1981).

The reproductive strategies and life cycles of these invasive insects further compound their threat. Most exhibit high fecundity, rapid development, and adaptability to various environmental conditions. Hemipteran species such as *Bemisia argentifolii* and *Myzus persicae* undergo incomplete metamorphosis and reproduce both sexually and asexually, including through parthenogenesis. This enables fast population growth under optimal conditions, with both nymphs and adults contributing to plant damage by feeding on phloem and transmitting viruses (CABI 1975).

Dipteran species like *Bactrocera dorsalis* (oriental fruit fly) undergo complete metamorphosis, with larvae feeding within fruits and causing substantial decay. These species have short life cycles—often just two to four weeks—and a wide host range, which accelerates their spread across diverse agroecological zones (Drew *et al.* 2003, Mwatawala *et al.* 2004).

Lepidopterans such as *Spodoptera frugiperda* and *Tuta absoluta* also undergo complete metamorphosis. Their larvae are particularly destructive, capable of consuming large amounts of foliage or boring into fruits, with females laying hundreds to thousands of eggs during their lifespans (Sisay *et al.* 2018). Such characteristics facilitate multiple generations per year, further compounding their invasiveness. Coleopterans such as *Prostephanus truncatus* and *Rhyzopertha dominica* target stored grains. Their larvae bore into kernels, rendering the produce unsuitable for consumption or sale.

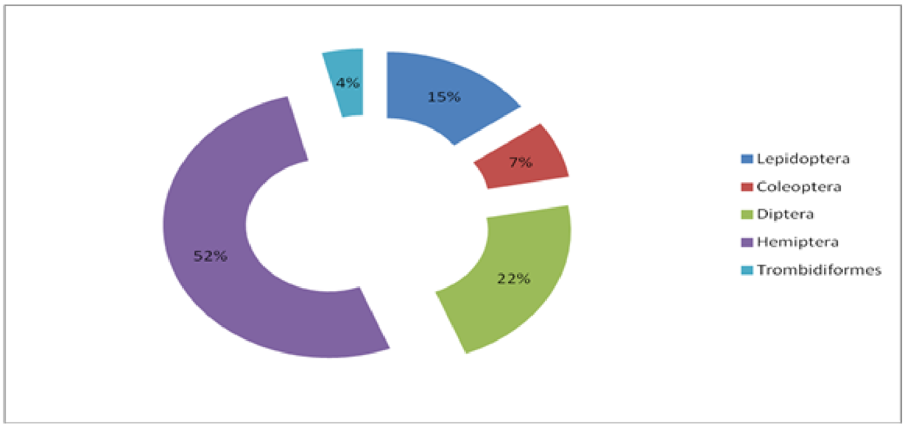

Figure 2. Representation of orders of Insect Invasive Species (IIS) in Tanzania.

These pests can survive for prolonged periods within storage structures, posing a persistent challenge to post-harvest management (Hodges *et al.* 1983). The sole representative of the Trombidiformes order, *Mononychellus tanajoa* (cassava green mite), reproduces rapidly and asexually, completing its life cycle in just 7–10 days. It significantly impairs cassava photosynthesis, reducing plant vigour and yields (Markham *et al.* 1987).

The extent of agricultural yield loss caused by these insects is substantial. For example, *Tuta absoluta* can lead to losses of up to 100% in tomatoes (Chidege *et al.* 2016), while *Chilo partellus* (spotted stem borer) can cause up to 100% loss in maize (January *et al.* 2020). The *Bemisia tabaci* complex (sweet potato whitefly) has been linked to yield reductions of up to 40% in various crops (Wosula *et al.* 2018). The cumulative impact of invasive insect species (IIS) in Tanzania significantly threatens food security, agricultural livelihoods, and ecological stability. These species not only disrupt local ecosystems but also exert substantial economic pressure on national and household levels, particularly among smallholder farmers who often lack the resources and adaptive capacity to cope with such disturbances. Invasive species like *Bactrocera invadens* are of particular concern due to their quarantine significance. Their introduction and spread have led to the imposition of strict phytosanitary measures, resulting in export restrictions on affected crops and consequently reducing foreign exchange earnings (Cooper *et al.* 2003). The loss of market access for agricultural commodities exacerbates economic vulnerability, especially for communities heavily reliant on horticultural exports.

Ecologically, IIS alter fundamental processes within ecosystems by preying on or outcompeting native species, leading to cascading effects on biodiversity and ecosystem functioning (Williams *et al.* 2019). In the Tanzanian context, such invasions have led to shifts in population dynamics, community structure, and nutrient cycles. Similar patterns were observed in New Zealand, where an invasive fish species disrupted stream ecosystems, altering food web structures and degrading ecosystem services (Townsend 2003). These parallels underscore the need for early intervention and long-term ecological monitoring.

Moreover, the presence of highly destructive pests in Tanzania has placed food security and rural livelihoods at critical risk. The damage to staple and cash crops leads to reduced yields, income loss, and increased food prices, further straining household resilience in already vulnerable regions (IITA 2015, Pratt *et al.* 2017, Jones & Brown 2018). This is particularly problematic in Tanzania, where agriculture is a key economic driver and a primary source of employment. Efforts to curb these biological invasions require integrated pest management (IPM), reinforced quarantine protocols, and regional cooperation. As Cooper *et al.* (2003) demonstrated in the South African context, stringent quarantine measures can be effective in halting the spread of alien species when implemented consistently and with adequate resources.

Table 3. Invasive Insect Pests Reported in Tanzania by Common Name, Scientific Name, Taxonomic Order, and Geographic Origin.

SN	Common name	Scientific name	Order	Origin	First report	Source
1	Larger grain borer	*Prostesphanus truncatus*	Coleoptera	Central America	1981	Dunstan & Magazini 1981
2	Lesser grain borer	*Rhyzopertha dominica*	Coleoptera	India	1983	Hodges *et al.* 1983
3	Fall armyworm	*Spodoptera frugiperda*	Lepidoptera	America	2017	Sisay *et al.* 2018
4	Diamond backmoth	*Plutella maculipennis*	Lepidoptera	Europe	2020	Christopher 2020
5	Spotted stem borer	*Chilo partellus*	Lepidoptera	Asia	2000	Overholt *et al.* 2000
6	Tomato leaf miner	*Tuta absoluta*	Lepidoptera	Peru	2014	Chidege *et al.* 2016
7	American serpentine leafminer	*Liriomyza trifolii*	Diptera	Caribbean	1992	Deeming 1992
8	Potato leaf miner	*Liriomyza huidobrensis*	Diptera	South America	2016	Mujica *et al.* 2016
9	Cassava mealy bug	*Phenacoccus manihoti*, *Phenacoccus manihot*	Hemiptera	Paraguay, Brazil	1987	Herren & Neuenschwander 1991
10	Sweet potato whitefly	*Bemisia argentifolii*	Hemiptera	America	2008	Aureus 2008
11	Papaya mealybug	*Paracoccus marginatus*	Hemiptera	Central America	2015	IITA 2015
12	Green peach aphid	*Myzus persicae*	Hemiptera	China	1975	CABI 1975
13	Mango mealybug	*Rastrococcus invadens*	Hemiptera	South-East Asia	2000	CABI 2000
14	Solanum whiteflies	*Aleurotrachelus trachoides*	Hemiptera	America	2018	Wosula *et al.* 2018
15	Coconut whiteflies	*Aleurotrachelus atratus*	Hemiptera	Brazil	2018	Wosula *et al.* 2018
16	Cottony cushion scale	*Icerya purchasi*	Hemiptera	Australia	1971	CABI 1971
17	Woolly white fly	*Aleurothrixus floccosus*	Hemiptera	South America	2015	Guastella *et al.* 2015
18	Guava whitefly	*Aleuroclava psidii*	Hemiptera	Asia	2014	Guastella *et al.* 2014

SN	Common name	Scientific name	Order	Origin	First report	Source
19	Loblolly pine bast scale	*Aleurotrachelus tuberculatus*	Hemiptera	Asia	2014	Guastella *et al.* 2014
20	Spiralling white fly	*Aleurodicus dispersus*	Hemiptera	Central America	2015	Guastella *et al.* 2015
21	Asian Citrus psyllid	*Diaphorina citri*	Hemiptera	Asia	2016	Shimwela *et al.* 2016
22	Invasive fruit fly	*Bactrocera invadens*	Diptera	Sri Lanka	2004	Mwatawala *et al.* 2004
23	Malaysian fruit fly	*Bactrocera latifrons*	Diptera	Asia	2006	Mwatawala *et al.* 2007
24	Melon fruit fly	*Bactrocera cucurbitae*	Diptera	India	2010	Mwatawala *et al.* 2010
25	Oriental fruit fly	*Bactrocera dorsalis*	Diptera	Taiwan	2003	Drew *et al.* 2003
26	Yellow sugarcane aphid	*Sipha flava*	Hemiptera	North America	2020	January *et al.* 2020
27	Cassava green mite	*Mononychellus tanajoa*	Trombidiformes	South America	1987	Markham *et al.* 1987

Table 4. Invasive Insect Pests in Tanzania: Life Cycle Types, Destructive Stages, and Potential Agricultural Yield Loss.

SN	Invasive insect	Scientific name	Life cycle	Destructive life stage	Potential yield loss	Source
1	Larger grain borer	*Prostesphanus truncatus*	Complete	Larvae and adult	5–45%	Golob 1988
2	Lesser grain borer	*Rhyzopertha dominica*	Complete	Larvae and adult	7.20%	Abass *et al.* 2013
3	Fall armyworm	*Spodoptera frugiperda*	Complete	Larvae	11–58%	Kansiime *et al.* 2023
4	Diamond backmoth	*Plutella maculipennis*	Complete	Larvae	90%	Ayalew 2006
5	Spotted stem borer	*Chilo partellus*	Complete	Larvae	60–100%	January *et al.* 2020
6	Tomato leaf miner	*Tuta absoluta*	Complete	Larvae	90–100%	Chidege *et al.* 2016
7	American serpentine leafminer	*Liriomyza trifolii*	Complete	Larvae	50% to >60%	Mujica & Kroschel 2013
8	Potato leaf miner	*Liriomyza huidobrensis*	Complete	Larvae	20–30%	Mujica *et al.* 2016

SN	Invasive insect	Scientific name	Life cycle	Destructive life stage	Potential yield loss	Source
9	Cassava mealy bug	*Phenacoccus manihoti*	Incomplete	Nymph, Adult	80%	Herren & Neuenschwander 1991
10	Sweet potato whitefly	*Bemisia tabaci*	Incomplete	Nymph, Adult	40%	Thresh *et al.* 1997
11	Papaya mealybug	*Paracoccus marginatus*	Incomplete	Nymph, Adult	75–100%	Mwanauta *et al.* 2022
12	Green peach aphid	*Myzus persicae*	Incomplete	Nymph, Adult	90%	WVC 2003
13	Mango mealybug	*Rastrococcus invadens*	Incomplete	Nymph, Adult	100%	Tanga 2012
14	Solanum whiteflies	*Aleurotrachelus trachoides*	Incomplete	Nymph, Adult	40%	Thresh *et al.* 1997
15	Coconut whiteflies	*Aleurotrachelus atratus*	Incomplete	Nymph, Adult	40%	Thresh *et al.* 1997
16	Cottony cushion scale	*Icerya purchasi*	Incomplete	Nymph, Adult	75%	Mwanauta *et al.* 2022
17	Woolly white fly	*Aleurothrixus floccosus*	Incomplete	Nymph, Adult	NA	NA
18	Guava whitefly	*Aleuroclava psidii*	Incomplete	Nymph, Adult	NA	NA
19	Loblolly pine bast scale	*Aleurotrachelus tuberculatus*	Incomplete	Nymph, Adult	NA	NA
20	Spiralling white fly	*Aleurodicus dispersus*	Incomplete	Nymph, Adult	NA	NA
21	Citrus psyllid	*Diaphorina citri*	Incomplete	Nymph, Adult	23%	Hodges *et al.* 2012
22	Fruit fly	*Bactrocera invadens*	Complete	Larvae	30–100%	Mwatawala *et al.* 2006, Vayssières *et al.* 2008
23	Malaysian fruit fly	*Bactrocera latifrons*	Complete	Larvae	NA	NA
24	Melon fruit fly	*Bactrocera cucurbitae*	Complete	Larvae	53%	Odanga *et al.* 2020
25	Oriental fruit fly	*Bactrocera dorsalis*	Complete	Larvae	15%	Vayssières *et al.* 2005
26	Yellow sugarcane aphid	*Sipha flava*	Incomplete	Nymph, Adult	45%	Madiope *et al.* 2021
27	Cassava green mite	*Mononychellus tanajoa*	Complete	Larvae and adult	20–80%	Annon 1999

NA denotes not available.

Table 5. Integrated Pest Management Approaches for Invasive Insect Species in Tanzania: Biological Control Agents, Chemical Insecticides, and Plant-Based Biopesticides.

SN	Invasive insect	Biological control	Chemical control	Biopesticides (extracts)
1	*Prostesphanus truncatus*	*Teretriosoma nigrescens* (Rees 1987)	Cypermethrin, Chlorfenapyr, Pirimiphos-methyl (Kavallieratos *et al.* 2017)	Neem, Tobacco (Osipitan *et al.* 2010)
2	*Rhyzopertha dominica*	*Anisopteromalus calandrae* (Menon *et al.* 2002)	Cypermethrin, Chlorfenapyr, Pirimiphos-methyl (Kavallieratos *et al.* 2017)	Salvia, Artemisia (Klys 2004)
3	*Spodoptera frugiperda*	*Coccygidium luteum* (Agboyi *et al.* 2020)	Chlorpyrifos, Cypermethrin, Malathion (Niassy *et al.* 2021)	*Azadirachta indica* seed extract (Silva *et al.* 2015)
4	*Plutella maculipennis*	*Diadegma* spp., *Cotesia plutellae* (Ayalew *et al.* 2004)	Deltamethrin, Cypermethrin (Ho *et al.* 1983)	*Capsicum*, *Cassia*, *Ocimum* (Amoabeng *et al.* 2013)
5	*Chilo partellus*	*Cotesia flavipes* (Overholt 2008)	Novaluron, Fipronil, Flubendiamide (Jindal *et al.* 2016)	Neem (Jindal *et al.* 2016)
6	*Tuta absoluta*	*Neochrysocharis formosa* (Ferracini *et al.* 2019)	Indoxacarb (Berxolli & Shahini 2018)	Neem (Berxolli & Shahini 2017)
7	*Liriomyza trifolii*	*Diglyphus isaea* (Chow & Heinz 2006)	Permethrin, Fenvalerate (Mason *et al.* 1987)	*Melia azedarach* (Banchio *et al.* 2003)
8	*Liriomyza huidobrensis*	*Diglyphus isaea* (Chow & Heinz 2006)	Permethrin, Fenvalerate (Mason *et al.* 1987)	*Melia azedarach* (Banchio *et al.* 2003)
9	*Phenacoccus manihoti*	*Epidinocarsis lopezi* (Neuenschwander 2001)	Methidathion (Atu & Okeke 1981)	*Elaeagnus latifolia* extract (Pumnuan *et al.* 2019)
10	*Bemisia tabaci*	Entomopathogenic fungi (Mascarin *et al.* 2013)	Flupyradifurone (Issa *et al.* 2022)	Neem, Jatropha (Diabate *et al.* 2014)
11	*Paracoccus marginatus*	*Anagyrus loecki* (Meyerdirk *et al.* 2004)	Sevin, Dimethoate, Deltamethrin (Biswas *et al.* 2015)	Neem oil, Mahogany oil (Biswas *et al.* 2015)
12	*Myzus persicae*	*Aphidius colemani* (Prado *et al.* 2015)	Imidacloprid, Acetamiprid (Rawat *et al.* 2013)	*Ocimum*, *Capsicum* (Dardouri *et al.* 2019)
13	*Rastrococcus invadens*	*Gyranusoidea tebygi* (Olufemi *et al.* 2000)	Chlorpyriphos-ethyl (Nebie *et al.* 2019)	*Ocimum*, *Cymbopogon*, *Eucalyptus* (Koffi *et al.* 2021)

SN	Invasive insect	Biological control	Chemical control	Biopesticides (extracts)
14	*Aleurotrachelus trachoides*	*Delphastus catalinae* (Avery *et al.* 2020)	NI	NI
15	*Aleurotrachelus atratus*	*Cordyceps fumosorosea* (Avery *et al.* 2020)	NI	NI
16	*Icerya purchasi*	*Rodolia cardinalis* (Causton *et al.* 2004)	Buprofezin (Mendel *et al.* 1991)	Clove extract (Mohanny *et al.* 2022)
17	*Aleurothrixus floccosus*	*Cales noakii* (Ogwang & Molo 2003)	Dimethoate (Fitiwy *et al.* 2019)	Tree tobacco, Neem extract
18	*Aleuroclava psidii*	*Encarsia cibcensis* (Abd-rabou & Evans 2017)	NI	NI
19	*Aleurotrachelus tuberculatus*	NI	NI	NI
20	*Aleurodicus disperses*	*Nephaspis oculatus* (Kumashiro *et al.* 1983)	Wheel powder/detergent (Islam *et al.* 2003)	Neem, Chili, Garlic extract (Sakthivel *et al.* 2011)
21	*Diaphorina citri*	*Isaria fumosorosea* (Kumar *et al.* 2017)	Thiamethoxam (Boina & Bloomquist 2015)	Neem, Datura extracts (Khan *et al.* 2014)
22	*Bactrocera invadens*	*Diachasmimorpha longicaudata* (Mohamed *et al.* 2008)	Malathion, Diazinon (Vargas *et al.* 2015)	Neem, Black pepper, *Seriphidium* (Jaleel *et al.* 2020)
23	*Bactrocera latifrons*	*Diachasmimorpha longicaudata* (Mohamed *et al.* 2008)	Malathion, Diazinon (Vargas *et al.* 2015)	Neem, Black pepper, *Seriphidium* (Jaleel *et al.* 2020)
24	*Bactrocera curcubitae*	*Diachasmimorpha longicaudata* (Mohamed *et al.* 2008)	Malathion, Diazinon (Vargas *et al.* 2015)	Neem, Black pepper, *Seriphidium* (Jaleel *et al.* 2020)
25	*Bactrocera dorsalis*	*Diachasmimorpha longicaudata* (Mohamed *et al.* 2008)	Malathion, Diazinon (Vargas *et al.* 2015)	Neem, Black pepper, *Seriphidium* (Jaleel *et al.* 2020)
26	*Sipha flava*	*Diomus terminatus* (Nuessly & Hentz 2002)	Lorsban, Baythroid (Beuzelin & May 2015)	Castor oil (Sotelo-Leyva *et al.* 2023)
27	*Mononychellus tanajoa*	*Neozygites tanajoae* (Delalibera *et al.* 2004)	Acaricide abamectin (Mutisya *et al.* 2015)	Neem extract (Silva *et al.* 2013)

NI denotes not identified.

Biological Control of Insect Invasive Species

Biological control methods utilise natural enemies to suppress invasive insect populations affecting agriculture and ecosystems in Tanzania. For example, *Prostephanus truncatus* is effectively managed by the parasitoid

Teretriosoma nigrescens (Rees 1987), while *Rhyzopertha dominica* can be controlled using the parasitic wasp *Anisopteromalus calandrae* (Menon *et al.* 2002). The parasitoid *Coccygidium luteum* is used to manage *Spodoptera frugiperda* (Agboyi *et al.* 2020). For *Plutella maculipennis*, parasitoid wasps such as *Diadegma* spp. and *Cotesia plutellae* are effective (Ayalew *et al.* 2004). In the case of *Tuta absoluta*, the parasitic wasp *Neochrysocharis formosa* has been employed (Ferracini *et al.* 2019).

Permethrin and fenvalerate were studied for their control of *Liriomyza huidobrensis* and *Liriomyza trifolii* (Mason *et al.* 1987), while methidathion and flupyradifurone have been applied to manage *Phenacoccus manihoti* (Atu & Okeke 1981). Flupyradifurone has also shown efficacy against *Bemisia tabaci* (Issa *et al.* 2022). Insecticides including Sevin, dimethoate, deltamethrin, imidacloprid, acetamiprid, and chlorpyriphos-ethyl have been used to manage *Paracoccus marginatus* and *Myzus persicae* (Rawat *et al.* 2013, Biswas *et al.* 2015).

Icerya purchasi has been controlled using buprofezin (Mendel *et al.* 1991), and dimethoate has been applied against *Aleurothrixus floccosus*. Alternative methods such as the use of detergent and wheel powder have been reported effective against *Aleurodicus dispersus* (Islam *et al.* 2003). Thiamethoxam, malathion, and diazinon have been used for *Bactrocera* species (Boina & Bloomquist 2015, Vargas *et al.* 2015). Lastly, *Sipha flava* and *Mononychellus tanajoa* have been managed using Lorsban, Baythroid, and abamectin (Beuzelin & May 2015, Mutisya *et al.* 2015).

Other botanicals include *Melia azedarach*, *Elaeagnus latifolia*, and *Ricinus communis*, used against *Liriomyza* spp., *Phenacoccus manihoti*, and *Sipha flava* (Banchio *et al.* 2003, Pumnuan *et al.* 2019; Sotelo-Leyva *et al.* 2023). Neem and mahogany oil combinations have been tested for *Paracoccus marginatus* (Biswas *et al.* 2015), while *Ocimum basilicum*, *Capsicum annuum*, and clove extract have been examined for *Myzus persicae* and *Icerya purchasi* (Dardouri *et al.* 2019; Mohanny *et al.* 2022). *Azadirachta indica* has also been tested extensively for *Mononychellus tanajoa* (Silva *et al.* 2013), and neem combined with datura has been used against *Diaphorina citri* (Khan *et al.* 2014).

CONCLUSION

The surge of invasive insect species in Tanzania represents a complex and escalating crisis, deeply intertwined with global trade dynamics, accelerating climate change, inherent ecological vulnerability, and persistent institutional limitations. While the nation's rich biodiversity and agro-ecological diversity underpin its agricultural potential, these same characteristics heighten susceptibility to biological invasions. The documented 27 IIS species, particularly the dominant Hemiptera, inflict severe and multi-dimensional damage across staple and cash crops, fundamentally undermining food security, farmer livelihoods, and national economic stability.

Effective management demands a holistic IPM approach, strategically leveraging biological control for sustainability, chemical control for essential rapid response, and biopesticides for enhanced environmental safety, all underpinned by robust local research, development, and extension. Ultimately, safeguarding Tanzania's agricultural future and ecological integrity demands a comprehensive, multi-sectoral response. This entails decisive strengthening of scientific capacity, fundamental reform of governance and biosecurity frameworks, empowerment of local communities through knowledge and resources, proactive fostering of regional and international cooperation, and the mainstreaming of invasive species management within national climate adaptation and food security strategies.

Only through such concerted, proactive, and sustained efforts can Tanzania hope to mitigate the profound threats posed by invasive insect pests and enhance the resilience of its vital agricultural systems against an increasingly uncertain future.

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