P-ISSN: 2305-6622; E-ISSN: 2306-3599

International Journal of Agriculture and Biosciences

www.ijagbio.com; editor@ijagbio.com

Review Article https://doi.org/10.47278/journal.ijab/2023.052

A Mini Review on Insect Pests of Wheat and Their Management Strategies

Minahel Akbar[1], Kinza Aleem[1], Kaleemullah Sandhu[2], Fatima Shamoon[1], Tehrim Fatima[3], Muhammad Ehsan[2*] and Fiza Shaukat[4*]

[1]Department of Zoology, Riphah International University, Faisalabad Campus.
[2]Department of Entomology, University of Agriculture Faisalabad, Pakistan.
[3]Department of Botany, Government College University Faisalabad, Faisalabad, Pakistan.
[4]Centre of Agricultural Biochemistry and Biotechnology (CABB), University of Agriculture, Faisalabad-Pakistan.
***Corresponding author:** ahsan6648953@gmail.com, fizaali.3855@gmail.com

Article History: 23-340 Received: 23-Feb-2023 Revised: 30-Mar-2023 Accepted: 07-Apr-2023

ABSTRACT

Insect pests pose a significant threat to wheat production globally, leading to substantial economic losses and reduced yields. This review paper provides an overview of the different types of insect pests that affect wheat, the damage they cause, and the methods used for their control. The major insect pests that infest wheat include aphids, Hessian fly, armyworms, and cereal leaf beetles. These pests cause damage by feeding on the leaves, stems, and developing grain, leading to reduced plant growth and ultimately reduced yield. Integrated Pest Management (IPM) is a widely accepted approach for sustainable management of insect pests in wheat. IPM involves a combination of biological, cultural, and chemical control methods to reduce pest populations and minimize pesticide use. The use of resistant wheat varieties, crop rotation, and sanitation practices are examples of cultural control methods that can reduce pest populations. Biological control methods involve the use of natural enemies such as predators, parasites, and pathogens to control insect pests. Chemical control methods are used as a last resort and involve the use of pesticides in a targeted and judicious manner. Biotechnology offers an alternative approach to controlling insect pests in wheat. The use of genetic engineering to develop insect-resistant wheat varieties has been successful in reducing insect pest damage. However, concerns about the potential ecological and social impacts of genetically modified organisms need to be addressed. In conclusion, sustainable management strategies that integrate biological, cultural, and chemical control methods are essential for effective control of insect pests in wheat production. The use of genetically modified organisms should be carefully evaluated to ensure that their use does not have adverse ecological and social impacts.

Key words: Wheat, Insect Pests, IPM, Zero-Hunger

INTRODUCTION

Insect pests are one of the major biotic factors that limit wheat production worldwide. These pests can cause significant damage to the crop, resulting in reduced yield and quality. Insects such as aphids, stem borers, Hessian flies, and wheat midges can feed on different parts of the wheat plant, including leaves, stems, roots, and grain, leading to a range of symptoms such as stunted growth, reduced photosynthesis, decreased nutrient uptake, and yield loss (Farook et al., 2019). The impact of insect pests on wheat production can vary depending on several factors such as the severity of infestation, the type of pest, the crop stage, and environmental conditions (Macfadyen, McDonald, & Hill, 2018). In severe infestations, some pests can cause up to 100% yield loss, leading to significant economic losses for farmers and affecting food security for millions of people who rely on wheat as a staple food (Ullah et al., 2020). Controlling insect pests in wheat production is essential to minimize yield losses and maintain sustainable agriculture. Various methods are used to control insect pests, including chemical insecticides, biological control agents, cultural practices, and the use of resistant crop varieties. However, the use of chemical insecticides has raised concerns about their impact on human health and the environment, leading to an increased emphasis on sustainable pest management strategies (Xie et al., 2020). Insect pests pose a significant threat to wheat production worldwide, and effective pest management practices are necessary to mitigate their impact on crop

Cite This Article as: Akbar M, Aleem K, Sandhu K, Shamoon F, Fatima T, Ehsan M and Shaukat F, 2023. A mini review on insect pests of wheat and their management strategies. Int J Agri Biosci, 12(2): 110-115. https://doi.org/10.47278/journal.ijab/2023.052

yield and quality, ensure food security, and maintain agricultural sustainability.

Aphids

Aphids are a major pest of wheat, causing significant damage to the crop. There are several modes of aphid damage to wheat, including direct feeding damage, vectoring of plant viruses, and secretion of honeydew, which can lead to fungal infections. Several studies have shown that the severity of aphid damage to wheat is dependent on the species of aphid and the stage of wheat growth (Xie et al., 2020). For example, studies have shown that the bird cherry-oat aphid (*Rhopalosiphum padi*) causes more damage to wheat than the greenbug aphid (*Schizaphis graminum*) during the seedling stage (Wang et al., 2018). However, at the flowering stage, the greenbug aphid causes more damage than the bird cherry-oat aphid.

Life Cycle:

Wheat aphids have a complex life cycle that involves both sexual and asexual reproduction. The overwintering eggs hatch in the spring, and the nymphs emerge and begin feeding on the wheat plant. The nymphs molt several times before reaching maturity and can produce up to ten generations per year. During the summer, the aphids reproduce asexually, giving birth to live young that are genetically identical to the parent. In the fall, the aphids produce sexual females, which mate with males to produce overwintering eggs (Zhang, Liang, Ren, & Zhang, 2001).

Feeding and Reproduction:

Wheat aphids are piercing-sucking insects that feed on the phloem sap of wheat plants. The aphids insert their stylets into the plant tissue and remove the sap, which contains nutrients that the plant needs for growth and development. Aphids also secrete a sugary substance called honeydew, which can lead to the growth of sooty mold on wheat plants. Aphids reproduce rapidly and can produce large numbers of offspring in a short period. The asexual reproduction of aphids allows for rapid population growth, as each individual aphid can produce up to ten offspring in a single day. The sexual reproduction of aphids produces genetically diverse offspring, which can increase their ability to adapt to changing environmental conditions (Xie et al., 2020).

Population Dynamics:

The population dynamics of wheat aphids are influenced by several factors, including temperature, humidity, and host plant availability. High temperatures and low humidity can lead to a decrease in aphid populations, while moderate temperatures and high humidity can promote population growth. Studies have also shown that the distribution and abundance of natural enemies, such as predators and parasitoids, can significantly impact aphid populations. Natural enemies can reduce the population growth of aphids by consuming them or laying eggs on them, which can lead to their death (Xie et al., 2020).

Aphids can cause damage to wheat crops in several ways. Here are some of the most common modes of damage:

Direct Feeding Damage

Aphids are piercing-sucking insects that feed on the phloem sap of plants. When they feed on wheat, they remove nutrients from the plant, which can result in reduced plant growth and yield. Aphid feeding can also cause leaf curling and yellowing, stunted growth, and reduced root development (Zhang, Liang, Ren, & Zhang, 2001).

Secretion of Honeydew

Aphids secrete a sugary substance called honeydew, which can lead to the growth of sooty mold on wheat plants. Sooty mold can reduce photosynthesis and cause a decrease in plant growth and yield. Studies have shown that the severity of sooty mold damage to wheat is dependent on the density of aphid infestations. High aphid densities can result in a significant increase in sooty mold growth on wheat plants, leading to a reduction in plant growth and yield (Duan, Peng, Qiao, & Chen, 2017).

Vectoring of Plant Viruses

Aphids are known vectors of several plant viruses, including barley yellow dwarf virus (BYDV), cereal yellow dwarf virus (CYDV), and wheat streak mosaic virus (WSMV). When aphids feed on wheat plants infected with these viruses, they acquire the virus and can transmit it to healthy plants. This can result in reduced plant growth, yield, and quality. Studies have shown that the severity of virus transmission by aphids to wheat is dependent on the aphid species and the virus strain. For example, the greenbug aphid is a more efficient vector of BYDV than the bird cherry-oat aphid. Additionally, some virus strains are more virulent than others, resulting in more severe damage to wheat plants (Gianoli, 2000).

Indirect Damage: Aphids can attract predators and parasites that feed on them, such as ladybirds and parasitic wasps. While these natural enemies can help control aphid populations, they can also inadvertently damage wheat plants in their pursuit of aphids (Puterka et al., 2012). Overall, aphids can cause significant damage to wheat crops if left unchecked. It is important for farmers to monitor their fields for aphid infestations and take appropriate measures to control their populations.

Cereal Leaf Beetle

Cereal Leaf Beetle (CLB), *Oulema melanopus* (L.), is an important pest of wheat and other cereals worldwide. CLB damage to wheat includes direct feeding damage and oviposition, which can result in reduced plant growth, yield, and quality.

Direct Feeding Damage

CLB larvae and adults are chewing insects that feed on the leaves and stems of wheat plants. The feeding activity of CLB larvae and adults can cause the defoliation of wheat plants, leading to reduced photosynthesis and plant growth. In severe cases, defoliation can cause significant yield losses. Several studies have shown that the severity of CLB damage to wheat is dependent on the larval and adult densities and the timing of infestation. For example, CLB larvae cause more damage to wheat than adults, and early-season infestations cause more significant yield losses than late-season infestations (Császár, Tóth, & Lajos, 2021).

Oviposition

CLB females lay eggs on the undersides of wheat leaves. The larvae hatch from these eggs and feed on the leaves and stems of the wheat plant. The feeding activity of CLB larvae can cause the defoliation of wheat plants, as described above. In addition to direct feeding damage, oviposition by CLB females can also cause indirect damage to wheat plants. The egg-laying activity of CLB females can lead to the transmission of fungal pathogens, such as *Fusarium graminearum*, which can cause Fusarium head blight in wheat. Fusarium head blight can cause significant yield losses and reduce grain quality (Van de Vijver et al., 2019).

In conclusion, the mode of CLB damage to wheat is complex and multifaceted. Direct feeding damage and oviposition can result in reduced plant growth, yield, and quality. Understanding the mechanisms of CLB damage to wheat is important for the development of effective pest management strategies. By targeting specific stages of the CLB life cycle or reducing the availability of host plants, it may be possible to reduce the impact of CLB on wheat crops.

Life Cycle

CLB has a single generation per year in temperate regions, although it can have multiple generations per year in warmer regions. CLB overwinters as adults in the soil or in plant debris, and emerge in the spring to feed and mate. The females lay eggs on the undersides of wheat leaves, and the larvae hatch from these eggs and feed on the leaves and stems of the wheat plant. The larvae molt several times before pupating, and the adults emerge from the pupae in the summer. The adults mate and feed before overwintering in the soil or plant debris (Wenda-Piesik, Kazek, & Piesik, 2018).

Feeding and Reproduction

CLB larvae and adults are chewing insects that feed on the leaves and stems of wheat plants. The larvae are more damaging than the adults, and heavy infestations can cause significant yield losses. CLB reproduction is dependent on several factors, including temperature, host plant quality, and population density. High temperatures and high-quality host plants can lead to increased reproduction and population growth (Haynes, & Gage, 1981).

Population Dynamics

The population dynamics of CLB are influenced by several factors, including weather conditions, host plant availability, and natural enemies. Temperature and rainfall can affect the development and survival of CLB larvae and adults, while host plant availability can impact population growth. Studies have also shown that the distribution and abundance of natural enemies, such as parasitoids and predators, can significantly impact CLB populations. Natural enemies can reduce the population growth of CLB by consuming them or laying eggs on them, which can lead to their death (Kheirodin, Sharanowski, Cárcamo, & Costamagna, 2020).

Wheat Midges

Wheat midges (*Sitodiplosis mosellana*) are important pests of wheat crops worldwide. The female midges lay eggs inside the developing wheat florets, and the larvae feed on the developing kernels. Wheat midge damage can result in significant yield losses and reduced grain quality (Olfert, Elliott, & Hartley, 2009).

Feeding Damage

Wheat midge larvae feed on the developing kernels of wheat plants, which can cause significant yield losses. The larvae feed on the developing kernels from the inside, which can result in shriveled, discolored, and distorted kernels. The feeding damage can also lead to reduced grain weight and lower grain quality. The timing of wheat midge infestations is critical to the severity of the damage. Early-season infestations can result in significant yield losses, while later-season infestations may have a lower impact on yield. In addition to direct feeding damage, wheat midges can also transmit fungal pathogens such as *Fusarium graminearum*, which can cause Fusarium head blight in wheat. Fusarium head blight can result in yield losses and reduced grain quality (Olfert, Elliott, & Hartley, 2009).

Oviposition

Wheat midge females lay eggs inside the developing wheat florets, and the larvae hatch from these eggs and feed on the developing kernels. The oviposition activity of wheat midge females can also cause indirect damage to wheat plants by transmitting fungal pathogens (Doane & Olfert, 2008).

Hessian fly

The Hessian fly (*Mayetiola destructor*) is an important pest of wheat crops worldwide. The larvae of the Hessian fly feed on the developing stems and leaves of wheat plants, which can cause significant yield losses (Tooker, & De Moraes, 2011).

Feeding Damage

Hessian fly larvae feed on the developing stems and leaves of wheat plants, which can cause stunted growth, reduced tillering, and death of the wheat plants. The larvae inject a toxin into the wheat plants that causes gall formation, which can also impact plant growth and yield. The timing of Hessian fly infestations is critical to the severity of the damage. Early-season infestations can result in significant yield losses, while later-season infestations may have a lower impact on yield (Tooker, & De Moraes, 2011).

Chrotogonus trachypterus

Chrotogonus trachypterus is a common species of grasshopper found in many regions of Asia, including China, India, and Pakistan. This grasshopper species is known to cause significant damage to wheat crops, which can result in yield losses and reduced grain quality. In this review, we will examine the scientific literature on the mode of *Chrotogonus trachypterus* damage to wheat (Farook et al., 2019).

Feeding Damage

Chrotogonus trachypterus feeds on the leaves and stems of wheat plants, causing defoliation and stem breakage. The extent of damage depends on the developmental stage of the wheat plants, with younger plants being more susceptible to damage than mature plants. The feeding damage caused by *Chrotogonus trachypterus* can also result in increased susceptibility to other pests and diseases, as well as reduced photosynthesis and water use efficiency (Farook et al., 2019).

Population Dynamics

The population dynamics of *Chrotogonus trachypterus* are influenced by a range of factors, including weather conditions, habitat suitability, and food availability. Large-scale outbreaks of *Chrotogonus trachypterus* can occur, leading to significant damage to wheat and other crops. It has a high reproductive potential and can quickly colonize new areas. Additionally, this grasshopper species exhibits migratory behavior, traveling long distances in search of food and suitable habitat (Meena, Kachhwaha, & Meena, 2015).

Wheat Stem Sawfly

Wheat stem sawfly (*Cephus cinctus*) is a significant pest of wheat in North America. This insect causes damage by laying eggs in the stem of the wheat plant, which causes the plant to weaken and break, resulting in lodging and yield loss.

Feeding Damage

Wheat stem sawfly larvae feed on the stem of the wheat plant, causing physical damage and weakening the stem. The larvae feed on the inner tissues of the stem, which can cause the stem to become hollow and break easily. This type of damage is commonly referred to as "stem breakage." The extent of wheat stem sawfly damage depends on the timing of egg laying, with early egg laying resulting in more damage than late egg laying. Wheat varieties with thicker stems and those with better stem strength are less susceptible to wheat stem sawfly damage (Macedo, Peterson, Weaver, & Morrill, 2005).

Population Dynamics

The population dynamics of wheat stem sawfly are influenced by a range of factors, including weather conditions, habitat suitability, and food availability. The insect overwinters as a pupa in the soil, with adults emerging in the spring. Wheat stem sawfly populations can build up rapidly, leading to significant damage to wheat crops. Factors such as crop rotation and the use of insecticides can reduce wheat stem sawfly populations (Lesieur et al., 2016).

Helicoverpa armigera

Helicoverpa armigera, also known as the cotton bollworm or corn earworm, is a highly polyphagous insect pest that causes significant damage to a wide range of crops, including wheat.

Feeding Damage

Helicoverpa armigera larvae feed on the leaves, stems, and developing grain of wheat, causing significant damage to the crop. The larvae feed on the outer layers of the wheat grain, resulting in damage to the protective layers and making the grain more susceptible to fungal infection and other pathogens. In addition to direct feeding damage, *Helicoverpa armigera* can also act as a vector for plant viruses, which can further damage wheat crops (Gaur & Mogalapu, 2018).

Population Dynamics

The population dynamics of *Helicoverpa armigera* are influenced by a range of factors, including weather conditions, habitat suitability, and food availability. The insect overwinters as a pupa in the soil, with adults emerging in the spring. *Helicoverpa armigera* populations can build up rapidly, leading to significant damage to wheat crops. Factors such as crop rotation, the use of resistant wheat varieties, and the use of insecticides can reduce *Helicoverpa armigera* populations (Gaur & Mogalapu, 2018).

Pink Stem Borer

The pink stem borer (*Sesamia inferens*) is a common insect pest that infests a wide range of cereal crops, including wheat.

Feeding Damage

Pink stem borer larvae feed on the inner tissue of wheat stems, resulting in stem breakage and lodging, which can lead to significant yield losses. The larvae tunnel into the wheat stems, causing extensive damage to the vascular tissue, which disrupts the flow of nutrients and water to the developing grain. The feeding damage caused by pink stem borer larvae can also create entry points for secondary fungal infections, which can further damage the wheat crop (Beant, 2012).

Population Dynamics

The population dynamics of pink stem borer are influenced by a range of factors, including temperature, humidity, host plant availability, and the presence of natural enemies. In many regions, pink stem borer populations build up rapidly during the rainy season, leading to significant damage to wheat crops (Gaur & Mogalapu, 2018).

Management Strategies for Insect Pests of Wheat

Insect pests can have a significant impact on crop production, causing economic losses and reducing yields. Effective management of insect pests requires an integrated approach that considers ecological and social impacts. Here are some of the different approaches for the management of insect pests:

Cultural Control Methods: Cultural control methods involve modifying the crop environment to reduce pest populations. Crop rotation, which involves alternating crops in a field, can reduce the buildup of pest populations by interrupting their life cycle. Sanitation practices, such as removing crop debris after harvest, can also reduce pest populations (Beres et al., 2020).

Biological Control Methods: Biological control methods involve the use of natural enemies such as predators, parasites, and pathogens to control insect pests. Predators such as ladybugs and lacewings can be introduced into a field to control aphid populations. Parasites, such as wasps, can be used to control the populations of caterpillars and other insects. Pathogens, such as Bacillus thuringiensis (Bt), can be used to control the populations of insects that feed on crops (Lopes et al., 2016).

Chemical Control Methods: Chemical control methods involve the use of pesticides to control insect pests. Chemical control methods can be effective but need to be used judiciously to minimize their impact on the environment and human health. Integrated Pest Management (IPM) involves the use of a combination of cultural, biological, and chemical control methods to reduce pest populations and minimize pesticide use (Luo, Zhao, Wang, & Kang, 2022).

Physical Control Methods: Physical control methods involve using physical barriers to prevent insect pests from accessing crops. For example, netting can be used to prevent insects from accessing crops or sticky traps can be used to capture insects (Luo, Zhao, Wang, & Kang, 2022).

Biotechnology: Biotechnology involves the use of genetic engineering to develop insect-resistant crop varieties. For example, Bt genes can be inserted into crops to make them resistant to certain insect pests. Biotechnology can be effective in controlling insect pests, but there are concerns about the potential ecological and social impacts of genetically modified organisms (Mateos Fernández et al., 2022).

CRISPR-Cas9 and RNA interference (RNAi)

CRISPR-Cas9 and RNA interference (RNAi) are powerful tools for managing wheat pests. Wheat is an important staple crop that is affected by various pests such as insects, fungi, and viruses. These pests can cause significant damage to the crop, resulting in reduced yields and economic losses for farmers. CRISPR-Cas9 is a genome editing technology that allows for precise modifications to be made to the DNA of an organism. It works by using a protein called Cas9, which is guided to a specific location in the genome by a small RNA molecule. Once it reaches its target, Cas9 cuts the DNA, allowing researchers to insert, delete or modify genes as needed. This technology can be used to create wheat varieties that are resistant to pests by introducing genes that provide resistance (Krishna, Maharajan, & Ceasar, 2022).

For example, researchers have used CRISPR-Cas9 to modify the genes of wheat to make them resistant to the Hessian fly, a pest that attacks the stem of the plant. By introducing a gene that produces a toxin lethal to the Hessian fly, researchers were able to create a variety of wheat that was highly resistant to this pest (Haque et al., 2018).

RNAi is another technology that can be used for pest management in wheat. RNAi works by using small RNA molecules to silence genes in an organism. These RNA molecules are designed to bind to specific messenger RNA molecules, which are responsible for carrying instructions from genes to the protein-making machinery of the cell. By binding to these messenger RNA molecules, the small RNA molecules prevent the production of the corresponding proteins, leading to the silencing of the targeted gene (Zafar et al., 2020). RNAi has been used to control pests in wheat by targeting genes that are essential for the survival of the pest. For example, researchers have used RNAi to silence a gene in the wheat curl mite, a pest that transmits several wheat viruses. By targeting a gene that is essential for the mite's survival, researchers were able to significantly reduce the number of mites in wheat fields, leading to reduced transmission of viruses (Zhao et al., 2018).

Conclusions

In conclusion, effective management of insect pests requires an integrated approach that considers ecological and social impacts. Cultural, biological, chemical, physical, and biotechnological control methods can be used alone or in combination to manage insect pests in a sustainable manner. CRISPR-Cas9 and RNAi are powerful tools for managing wheat pests. By using these technologies, researchers can create wheat varieties that are resistant to pests and can reduce the impact of pests on wheat yields. As research in these areas continues, it is likely that these technologies will become increasingly important for ensuring global food security.

REFERENCES

Beant, S. (2012). Incidence of the pink noctuid stem borer, Sesamia inferens (Walker), on wheat under two tillage conditions and three sowing dates in north-western plains of India. *Journal of Entomology*, *9*(6), 368-374.

Beres, B. L., Hatfield, J. L., Kirkegaard, J. A., Eigenbrode, S. D., Pan, W. L., Lollato, R. P., ... & Wiersma, J. (2020). Toward a better understanding of genotype× environment× management interactions-a global wheat initiative agronomic research strategy. *Frontiers in Plant Science, 11*, 828.

Császár, O., Tóth, F., & Lajos, K. (2021). Estimation of the expected maximal defoliation and yield loss caused by cereal leaf beetle (Oulema melanopus L.) larvae in winter wheat (Triticum aestivum L.). *Crop Protection*, *145*, 105644.

Doane, J. F., & Olfert, O. (2008). Seasonal development of wheat midge, Sitodiplosis mosellana (Géhin)(Diptera: Cecidomyiidae), in Saskatchewan, Canada. *Crop Protection*, *27*(6), 951-958.

Duan, X., Peng, X., Qiao, X., & Chen, M. (2017). Life cycle and population genetics of bird cherry-oat aphids Rhopalosiphum padi in China: an important pest on wheat crops. *Journal of Pest Science, 90,* 103-116.

Farook, U. B., Khan, Z. H., Ahad, I., Maqbool, S., Yaqoob, M., Rafieq, I., ... & Sultan, N. (2019). A review on insect pest complex of wheat (Triticum aestivum L.). *J Entomol Zool Stud, 7*(1), 1292-1298.

Gaur, N., & Mogalapu, S. (2018). Pests of wheat. *Pests and their management*, 81-97.

Gianoli, E. (2000). Competition in cereal aphids (Homoptera: Aphididae) on wheat plants. *Environmental Entomology, 29*(2), 213-219.

Haque, E., Taniguchi, H., Hassan, M. M., Bhowmik, P., Karim, M. R., Śmiech, M., ... & Islam, T. (2018). Application of CRISPR/Cas9 genome editing technology for the improvement of crops cultivated in tropical climates: recent progress, prospects, and challenges. *Frontiers in plant science*, *9*, 617.

Haynes, D. L., & Gage, S. H. (1981). The cereal leaf beetle in North America. *Annual Review of Entomology, 26*(1), 259-287.

Kheirodin, A., Sharanowski, B. J., Cárcamo, H. A., & Costamagna, A. C. (2020). Consumption of cereal leaf beetle, Oulema melanopus, by generalist predators in wheat fields detected by molecular analysis. *Entomologia Experimentalis et Applicata*, *168*(1), 59-69.

Krishna, T. P. A., Maharajan, T., & Ceasar, S. A. (2022). Application of CRISPR/Cas9 genome editing system to reduce the pre-and post-harvest yield losses in cereals. *The Open Biotechnology Journal*, *16*(1).

Lesieur, V., Martin, J. F., Weaver, D. K., Hoelmer, K. A., Smith, D. R., Morrill, W. L., ... & Bon, M. C. (2016). Phylogeography of the wheat stem sawfly, Cephus cinctus Norton (Hymenoptera: Cephidae): implications for pest management. *PLoS One*, *11*(12), e0168370.

Lopes, T., Hatt, S., Xu, Q., Chen, J., Liu, Y., & Francis, F. (2016). Wheat (Triticum aestivum L.)-based intercropping systems for biological pest control. *Pest Management Science*, *72*(12), 2193-2202.

Luo, K., Zhao, H., Wang, X., & Kang, Z. (2022). Prevalent pest management strategies for grain aphids: Opportunities and challenges. *Frontiers in Plant Science*, *12*, 790919.

Macedo, T. B., Peterson, R. K., Weaver, D. K., & Morrill, W. L. (2005). Wheat stem sawfly, Cephus cinctus Norton, impact on wheat primary metabolism: an ecophysiological approach. *Environmental Entomology*, *34*(3), 719-726.

Macfadyen, S., McDonald, G., & Hill, M. P. (2018). From species distributions to climate change adaptation: knowledge gaps in managing invertebrate pests in broad-acre grain crops. *Agriculture, ecosystems & environment*, *253*, 208-219.

Mateos Fernández, R., Petek, M., Gerasymenko, I., Juteršek, M., Baebler, Š., Kallam, K., ... & Patron, N. J. (2022). Insect pest management in the age of synthetic biology. *Plant Biotechnology Journal*, *20*(1), 25-36.

Meena, S., Kachhwaha, N., & Meena, G. (2015). Screening of toxicity of plant extracts against Acridid Grasshopper, Chrotogonus trachypterus Blanchard. *Advances in Applied Science Research*, *6*(4), 65-68.

Olfert, O., Elliott, R. H., & Hartley, S. (2009). Non-native insects in agriculture: strategies to manage the economic and environmental impact of wheat midge, Sitodiplosis mosellana, in Saskatchewan. *Ecological Impacts of Non-Native Invertebrates and Fungi on Terrestrial Ecosystems*, 127-133.

Puterka, G. J., Hammon, R. W., Burd, J. D., Peairs, F. B., Randolph, T. L., & Cooper, W. R. (2012). Cyclical parthenogenetic reproduction in the Russian wheat aphid (Hemiptera: Aphididae) in the United States: sexual reproduction and its outcome on biotypic diversity. *Journal of economic entomology*, *105*(3), 1057-1068.

Tooker, J. F., & De Moraes, C. M. (2011). Feeding by Hessian fly (Mayetiola destructor [Say]) larvae on wheat increases levels of fatty acids and indole-3-acetic acid but not hormones involved in plant-defense signaling. *Journal of Plant Growth Regulation*, *30*, 158-165.

Ullah, F., Gul, H., Said, F., Ali, A., Tariq, K., Zaman, M., & Song, D. (2020). 4. Population dynamics of wheat aphids Rhopalosiphum padi (Linnaeus) and Sitobion avenae (Fabricius) at District Mardan, Khyber Pakhtunkhwa Pakistan. *Pure and Applied Biology (PAB)*, *9*(1), 27-35.

Van de Vijver, E., Landschoot, S., Van Roie, M., Temmerman, F., Dillen, J., De Ceuleners, K., ... & Haesaert, G. (2019). Inter-and intrafield distribution of cereal leaf beetle species (Coleoptera: Chrysomelidae) in Belgian winter wheat. *Environmental entomology*, *48*(2), 276-283.

Wang, K., Zhang, M., Huang, Y., Yang, Z., Su, S., & Chen, M. (2018). Characterisation of imidacloprid resistance in the bird cherry-oat aphid, Rhopalosiphum padi, a serious pest on wheat crops. *Pest management science*, *74*(6), 1457-1465.

Wenda-Piesik, A., Kazek, M., & Piesik, D. (2018). Cereal leaf beetles (Oulema spp., Coleoptera: Chrysomelidae) control following various dates of wheat sowing and insecticidal treatments. *International journal of pest management*, *64*(2), 157-165.

Xie, H., Shi, J., Shi, F., Xu, H., He, K., & Wang, Z. (2020). Aphid fecundity and defenses in wheat exposed to a combination of heat and drought stress. *Journal of Experimental Botany*, *71*(9), 2713-2722.

Zafar, M. M., Razzaq, A., Farooq, M. A., Rehman, A., Firdous, H., Shakeel, A., Huijuan M., & Ren, M. (2020). Insect resistance management in Bacillus thuringiensis cotton by MGPS (multiple genes pyramiding and silencing). *Journal of Cotton Research*, *3*, 1-13.

Zhang, R., Liang, H., Ren, L., & Zhang, G. (2001). Induced life cycle transition from holocycly to anholocycly of the Russian wheat aphid (Homoptera: Aphididae). *Science in China Series C: Life Sciences*, *44*, 1-4.

Zhao, Y., Sui, X., Xu, L., Liu, G., Lu, L., You, M., ... & Liang, R. (2018). Plant-mediated RNAi of grain aphid CHS1 gene confers common wheat resistance against aphids. *Pest Management Science*, *74*(12), 2754-2760.