Biological Control of Barley Yellow Dwarf Virus (BYDV) Vector Aphid Using *Coccinella septempunctata* and *Coccinella undecimpunctata* in Barley and Wheat

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ABSTRACT

Crop diseases lead to significant losses in food production and economies. Crops are not food for human and animal consumption alone but also for a host of microbial pathogens and insect pests such as aphids. Researchers often study the impact of one pathogen on a particular plant species in isolation instead of considering other pathogens that share the environment. Somehow, agroecological zones support conditions favoring other pathogens and their vectors, which considerably clouds the ability to properly attribute crop losses to disease and target resources for resistance, especially concerning pesticide use. This study briefly describes biological resistance against aphids, being the major vectors of barley yellow dwarf virus (BYDV), a viral pathogen of great economic importance on wheat and barley. Adult and nymphal aphids weaken the plants by having their mouthparts inserted to withdraw plant cell sap. The infested plants develop pale silky leaves, eventually wilting. By excreting honeydew, aphids stimulate sooty mold growth on leaves that hinders photosynthesis. The biological control agents counteract these pests. Ladybird beetles (Coccinellidae), are part of the diverse biocontrol agents occurring throughout the terrestrial ecosystems. The beetles, part of the order Coleoptera, suborder Polyphaga, superfamily Cucujoidea, and family Coccinellidae. Crop diseases cause major yield and quality losses and threaten wheat and barley production. This study evaluates the potential of *Coccinella septempunctata* and *Coccinella undecimpunctata* as biological control agents against aphids, the primary vectors of barley yellow dwarf virus. Greenhouse and laboratory experiments were conducted using barley and wheat seedlings infested with aphid species, while the beetles were reared under controlled conditions. Feeding rates were measured at different constant temperatures, revealing that aphid consumption increased with temperature and peaked at 27°C. *C. undecimpunctata* consistently consumed more aphids than *C. septempunctata*. These results support the use of these ladybird beetles as effective biological control agents that can reduce reliance on chemical pesticides and help control virus transmission in cereal crops.

Keywords: barley, yellow dwarf virus, biological control, *Coccinella septempunctata*, *Coccinella undecimpunctata*, *Rhopalosiphum padi*, *Diuraphis noxia*.

INTRODUCTION

Wheat plays a vital role in the global food supply, contributing to approximately one-fifth of the total calories consumed by the world's 7.9 billion people each year. The United Nations (2022) projections estimate that the global population will approach 10 billion by 2050. This ever-growing population will continue to drive the demand for food. Looking ahead, experts predict that global agricultural production must double by 2050 to meet this increased demand, while also considering the impacts of climate

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change and other natural factors, such as agricultural pests and diseases, on long-term agricultural trends (Tilman et al ., 2011; Ray et al., 2013; Pardey et al., 2014; Omar et al., 2021).

Barley is one of the oldest domesticated crops. In the 2020/2021 season, global barley production reached 160.23 million tons, ranking it fourth among cereals, following maize, rice, and wheat (FAO STAT, 2022). It is recognized for its high nutritional value, containing significant protein, various chemical compounds, essential elements, and dietary fibers. Barley grains are primarily used in the malt industry as a traditional method of preparation and in human food across different regions of the world (Poehlman, 1994). Until the sixteenth century, barley flour was commonly used to make bread instead of wheat (Bukantis and Goodman, 1980). In Egypt, barley is mainly cultivated for animal feed (grain and straw), the brewing industry, and bread-making by Bedouins. The crop is known for its resilience to both biotic and abiotic stresses its ability to adapt to climate change. However, barley yields can be highly variable due to losses from various biological threats, such as diseases, insects, animals, and weeds, which can impact crop quality, taste, nutrition, and food safety (Wheeler and Reynolds, 2013, Sayed et al., 2019; Mohdly et al., 2024; Negm et al., 2025).

Wheat and barley viruses and their insect vectors contribute to significant crop losses worldwide. Climate change is expected to create more favorable conditions in northern wheat and barley cultivation regions in Egypt, increasing the spread of these diseases. Insects transmitting viruses will play an increasingly important role. As a result, there is an ongoing need to develop effective biocontrol methods, particularly as viral diseases and their insect vectors become more prevalent. One of the most environmentally friendly, safe, and effective approaches for controlling viral diseases in wheat and barley is the use of ladybird beetles (Coleoptera: Coccinellidae), which belong to the Coleoptera order, Polyphagia suborder, Cucujoidea superfamily, and Coccinellidae family. Most coccinellids are predatory, feeding on various pests such as aphids, thrips, small larvae, mites, and fungi (Sharawi, et al., 2025). Their potential for managing pests in economically important crops is immense. Both adult and larval stages are predatory, consuming various pests. As natural pest controllers, ladybird beetles are much more efficient than harmful chemicals, and their presence in agroecosystems helps reduce the need for dangerous chemical pesticides. This study focuses on the role of coccinellids as biological control agents for aphids, the vectors of the major viral pathogens affecting wheat and barley, particularly the barley yellow dwarf virus (BYDV).

MATERIAL AND METHODS

Seedling stage

Seedlings of the barley cultivar Giza 2000 and the wheat cultivar Morocco, both highly susceptible to infection, were used to sustain an aphid population. The plants were cultivated in a greenhouse at the Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt, during the 2023/2024 growing season. The greenhouse environment was maintained with 16 hours of light and 8 hours of darkness, with temperatures ranging from 16°C to 22°C. The plants were grown in plastic pots with an upper diameter of 9 cm. Artificial infestation was performed by introducing aphids when the plants reached 10 days of age, when the second leaf began to develop.

Methods enhancing *coccinellids* and aphids

Seven-spotted ladybirds, *Coccinella septempunctata*, and ten-spotted ladybirds, *Coccinella undecimpunctata*, were collected from natural habitats and used in the experiments. These ladybirds were reared in cages (40 × 40 × 80 cm) and fed on bird barley aphids (*Rhopalosiphum padi*) and wheat aphids (*Diuraphis noxia*). The aphids were raised on their specific host plants: *R. padi* on barley (*Hordeum vulgare* cv. Giza

2000) and *D. noxia* on wheat (*Triticum aestivum* cv. Morocco).

The ladybirds were maintained under the same conditions as the test plants. Ten plants per pot were infested with *R. padi* and *D. noxia* at the two-leaf stage (10 aphids per plant). Seven days post-infestation, the plants were used for bioassays (2018). Each pot, containing ten treated plants, was placed inside a Plexiglas cylinder (10 cm in diameter, 40 cm in height). The top of the cylinder was sealed with a square of transparent fabric, secured with a rubber band, to ensure visibility of aphids on the ground. The soil in the pot was covered with white sand, which was kept wet since ladybirds had poor traction on dry sand. Before the beetles were introduced to the experiment, they were starved for 24 hours.

Insect feeding rate

Various treatments were used to assess the feeding rate of ladybirds on aphids. Plants infested with barley aphids (*Rhopalosiphum padi*) and wheat aphids (*Diuraphis noxia*) each had one ladybird introduced into the cylinder. The ladybirds were provided access to water via a cotton plug connected to a water source placed near the plants. The feeding rate of the ladybirds was recorded over a 15-day experimental period, with observations made at 5, 10, and 15 days.

RESULTS AND DISCUSSION

Coccinellid beetles, which prey on aphids, are beneficial predators of crop pests and play a vital role in developing biological control strategies. Field observations have shown that temperature significantly impacts predation rates, with Coccinella beetles being more effective predators at higher temperatures than at lower ones. High temperatures are positively associated with the abundance of Coccinella beetles and are more easily observed when temperatures rise. These beetles have been observed feeding on aphids since early February and collected from barley and wheat plants grown at the Sakha, Nubariya, Giza, and Fayoum research stations.

We have examined the components of the predation process in detail in the laboratory to predict the actual predation rate. The adult seven-spotted *C. septempunctata* ladybird, which measures about 7-8 mm, has an oval, dome-shaped body with a white or pale spot on each side of the head. The black spot pattern on its body typically follows a 1-4-2 arrangement, with red or orange forewings. Similarly, the adult ten-spotted *C. undecimpunctata* beetle, also 7-8 mm in size, has an oval to dome-shaped body and lacks the white spots on its head. The black spots on its body are typically arranged in a 3-4-3 pattern, with red or orange forewings (Figure 1).

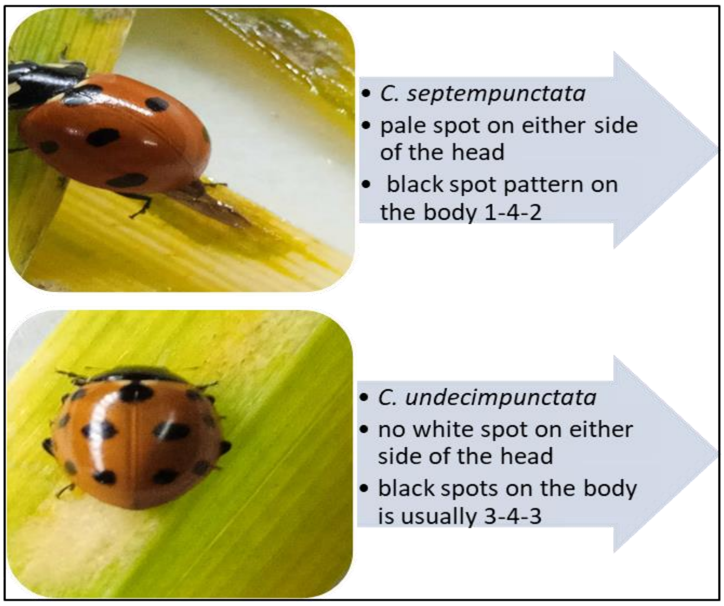

Figure 1. Adult of *C. septempunctata* and *C. undecimpunctata*

Effect of temperature on feeding rate

The relationship between temperature (day-degree) and the feeding rate of *C. septempunctata* and *C. undecimpunctata* is summarized in Table 1. Both species showed varying aphid consumption at different temperatures (17°C, 22°C, and 27°C). At all temperatures, *C. undecimpunctata* consumed more aphids than *C. septempunctata*. The total aphid consumption by *C. undecimpunctata* was 11.3, 14.5, and 18.3 aphids at 17°C, 22°C, and 27°C, respectively, while *C. septempunctata* consumed 9.2, 12.4, and 15.6 aphids at those temperatures. The highest daily consumption of aphids occurred at 27°C. This temperature is optimal for the activity and spread of aphids, particularly those infected with wheat and barley dwarf and yellowing virus, as well as healthy plants, making it an ideal condition for controlling aphid vectors.

Thus, Coccinella species can effectively manage aphid populations and help control the spread of BYDV by targeting aphid vectors. Furthermore, this confirms the importance of allowing aphids time to acquire and inoculate the virus, emphasizing the value of using Coccinella beetles as biological control agents.

The diet of parasitic insects primarily consists of aphids and other food sources such as pollen and fungal spores. The feeding rate of beetles on barley aphids (*Rhopalosiphum padi*) and wheat aphids (*Diuraphis noxia*) was tested by measuring daily aphid consumption. The average number of aphids consumed by each insect on days 5, 10, and 15 significantly differed between the two coccinellid species under laboratory conditions at 23°C with a 16-hour light photoperiod (Table 2 and Figure 2). The results clearly indicate that the highest average daily feeding rate occurred on day 5, with *C. septempunctata* consuming 36.1 aphids and *C. undecimpunctata* consuming 39.1 aphids. The feeding rate decreased as the number of days increased, likely due to the insects' starvation prior to the start of the experiment, which was observed in both coccinellid species.

Table 1. Mean daily consumption of *C. septempunctata* and *C. undecimpunctata* reared on Aphids at three constant temperatures

Species (beetles)	Temperature (°C)					
	17°C		22°C		27°C	
	N*	MF**	N	MF	N	MF
C. septempunctata	5	9.2	5	12.4	5	15.6
C. undecimpunctata	5	11.3	5	14.5	5	18.3

*N: Number of Individuals were examined; **MF: Mean Feeding rate on Aphid.

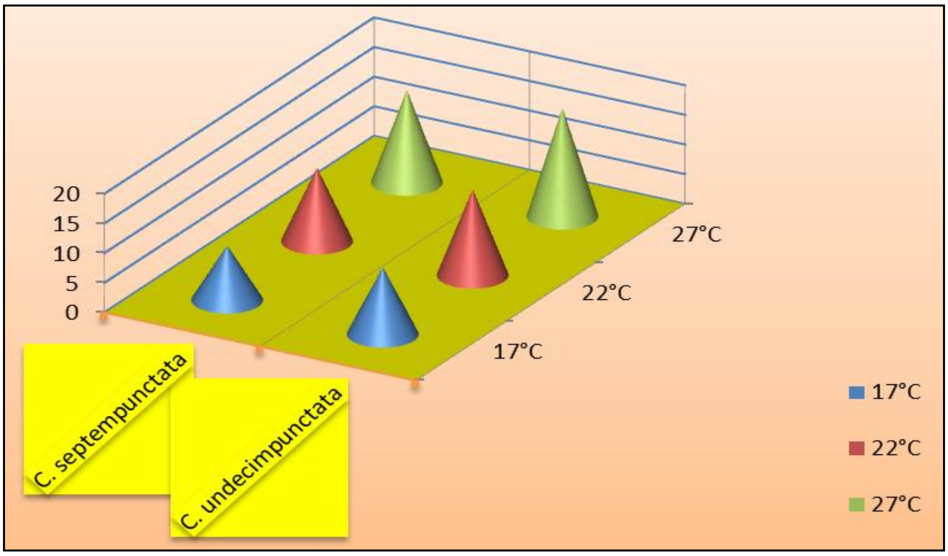

Figure 2. Feeding rate of *C. septempunctata* and *C. undecimpunctata* on Aphid at

Significant differences were observed in aphid consumption across the 5, 10, and 15-day periods between the two species. The total average consumption of five insects was significantly higher in *C. undecimpunctata*, with consumption reaching 191.1, 332.2, and 491.6 aphids on days 5, 10, and 15, respectively, compared to *C. septempunctata*, which consumed 173.9, 317.8, and 478.1 aphids over the same periods. These findings suggest that, in the case of aphid-borne BYDV, coccinellid species can be utilized to control aphid populations during the early post-emergence phase of crops. This supports the effectiveness of using coccinellids as biological control agents for managing aphid populations in field conditions (Video 1).

Table 2. Mean daily consumption of Aphid by *C. septempunctata* and *C. undecimpunctata* reared during 15 days

Species (beetles)	Days					
	5		10		15	
	N*	MF**	N	MF	N	MF
C. septempunctata	1	35.4	1	63.3	1	96.1
	1	33.3	1	64.1	1	96.3
	1	34.2	1	62.3	1	95.7
	1	36.1	1	64.4	1	94.9
	1	34.9	1	63.7	1	95.1
	Total	173.9	Total	317.8	Total	478.1
C. undecimpunctata	1	38.1	1	65.5	1	99.3
	1	39.1	1	67.3	1	97.5
	1	38.3	1	66.4	1	99.1
	1	36.3	1	65.9	1	98.3
	1	38.3	1	67.1	1	97.4
	Total	191.1	Total	332.2	Total	491.6
L.S.D. at 0.05	19.19		18.86		29.39	

*N: Number of Individuals were examined; **MF = Mean Aphid feeding rate in 5 days.

Figure 3. Coccinella undecimpunctata feeding on Aphid wheat and barley

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Video 1. Video explaining *Coccinella undecimpunctata* mealybugs
observed since the beginning of January feeding on Aphid wheat and barley

Barley yellow dwarf virus (BYDV) is a significant issue for wheat and barley production, and current climate change is creating favorable conditions that make BYDV a major concern for these crops (Săulescu et al., 2011; Jones, 2021). This virus is transmitted by aphids and has the potential to reduce wheat yields by 11-33% (Walls et al., 2019). Barley aphids (*Rhopalosiphum padi*) and wheat aphids (*Diuraphis noxia*) feed on and transmit the virus to wheat, oats, rye, corn, and barley, as well as to over 150 other grass species in the Poaceae family (Miller and Rasochová, 1997). Due to the wide host range and complex life cycle of the BYDV vectors, effective control is critical.

In this study, we explored biological resistance to aphids and their daily consumption at varying temperatures by the predators *C. septempunctata* and *C. undecimpunctata*. Feeding rates increased with temperature for both predator species. Similar findings were reported for *C. septempunctata* larvae, which consumed adult *M. persicae nicotianae* at higher rates as temperatures rose (Snyder et al., 2004). The highest mean consumption rate was observed at 27°C for both predator species. Pervez and Omkar (2006) also found the highest aphid consumption by *C. septempunctata* at 23°C, while Ellingsen (1969) reported that temperature fluctuations between 8°C and 28°C led to increased total consumption by *A. bipunctata* larvae.

Hodek and Evans (2012) suggest that beetles may compensate for higher evaporative water loss by consuming more prey with higher water content at elevated temperatures. These findings are valuable for comparing beetle species and improving our understanding of their population dynamics. Coccinellid beetles play a crucial role in agroecosystems by preying on a variety of harmful insect pests (Agarwala et al., 1988).

The effectiveness of coccinellids as biological control agents can be enhanced by utilizing various strategies. For instance, spraying nutrients like sucrose on crops can boost the reproductive rate of coccinellids. While ladybugs cannot sting, they likely deter predators by having a bad taste and emitting an unpleasant odor, possibly through a fluid released from joints in their legs. They may also "play dead" when threatened, as many predators avoid insects that do not move (Fleming, 2000). The bright colors of ladybird beetles serve as a warning to predators that they are toxic. When disturbed, some species can release a strong-smelling yellow liquid as a defense mechanism.

Coccinellids are multivoltine, producing several generations per year. Their life cycle includes four stages: egg, larva, pupa, and adult. These beetles show great potential in controlling insect pests and fungus-sooty molds. A key characteristic of successful biological control agents is their gluttony, which is demonstrated in this study, where adults of *C. undecimpunctata* and *C. septempunctata*, due to starvation before the experiment, consumed more aphids over a 15-day period, effectively controlling high aphid populations. Similar findings were reported by Dixon (2000).

DeBach (1964) defines biological control as the process where infections, parasites, or predators help maintain the average population density of other organisms below what it would be in their absence. Biological control is an environmentally friendly method of reducing insect populations to below economic threshold levels by utilizing natural pest enemies, posing no risk of environmental contamination or harm to human health or domestic animals. To optimize the growth of coccinellids for biological control, a comprehensive approach is necessary, with a shift away from the traditional reliance on pesticides and fungicides. For biological control to be successful, the prey population should be minimally disturbed, which can be achieved by reducing pesticide use (both insecticides and fungicides). Although pesticides effectively reduce prey populations, they harm the environment.

Biological control, being environmentally friendly, has a much lower impact on human health and domestic animals. Ladybird beetles can be combined with other predators or parasitoids for more effective pest control.

Successful collaboration between plant pathologists, breeders, entomologists, and wheat and barley production specialists can lead to agricultural systems that maintain soil health with minimal pesticide use, thereby reducing environmental damage.

Coccinellidae as a biocontrol agent plays an important role in the reduction of BYDV spread due to a decline in the aphid population. Ladybird beetles, when introduced into agricultural settings, effectively predate on aphids, bringing their population significantly low. This reduction in aphid population directly relates to the reduced virus transmission rate within wheat and barley crops (Hodek and Evans, 2012). Indeed, it has been revealed that the ladybird beetles, particularly *Coccinella septempunctata* and *Coccinella undecimpunctata*, have a high predatory impact on aphids, thus breaking the virus transmission cycle (Dixon, 2000). Moreover, for BYDV acquisition and inoculation, the aphids require a certain feeding period, and their predation significantly reduces the possibility of viral transmission (Walls et al., 2019). Given the short reproductive cycle of aphids, early intervention by natural predators is essential to prevent exponential growth among vector populations. The use of Coccinellidae in integrated pest management programs provides an active form of disease suppression that reduces reliance on chemical treatments (De Bach, 1964).

Beyond its immediate role in aphid control, the adoption of ladybird beetles in agricultural systems aligns with the principles of sustainable farming. Unlike chemical pesticides, which can disrupt the ecological balance, contaminate soil, and pose risks to non-target organisms, biological control methods offer an environmentally responsible alternative (Perdikis et al., 2011). Integrated Pest Management (IPM) programs that incorporate natural predators like Coccinellidae not only reduce the ecological footprint of agricultural practices but also promote soil health and biodiversity (Snyder et al., 2004). Additionally, by minimizing pesticide use, farmers can enhance crop quality, lower production costs, and meet increasing consumer demand for eco-friendly agricultural products (Gurr et al., 2003). The long-term benefits of biological control extend beyond immediate pest suppression, contributing to the resilience of agricultural ecosystems against climate-induced pest outbreaks (Bale et al., 2008). Thus, leveraging Coccinellidae as a sustainable biocontrol solution is a key step toward fostering a more resilient and environmentally conscious agricultural sector.

CONCLUSIONS

This study investigates the biological control of *Rhopalosiphum padi* and *Diuraphis noxia*, the two most important aphid vectors of barley yellow dwarf virus, by using *Coccinella septempunctata* and *Coccinella undecimpunctata* as natural predators. Our research shown that temperature affects the predation rate of aphids, and higher temperatures increase the efficiency of predation. The results highlight the potential of ladybird beetles to serve as a biological alternative to chemical pesticides in mitigating virus transmission at minimal environmental cost.

These results confirm the need to develop eco-friendly pest control practices that enhance the resilience and productivity of crops, reducing reliance on chemical treatments.

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