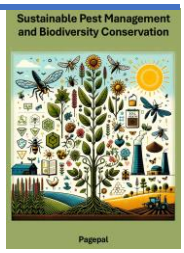
Sustainable Pest Management and Biodiversity Conservation
https://journals.pagepal.org/index.php/SPMBC
ISSN (Online), 3080-2458; (Print), 3080-244X
https://doi.org/ 10.54219/spmbc.04.01.2025.419



Biosafety evaluation of selected synthetic and botanical pesticides on the life parameters of seven spotted ladybird beetle, *Coccinella septempunctata* L. (Coleoptera: Coccinellidae)

***Muhammad Ismail*[1*], *Rakhshanda Jabeen*[1], *Muhammad Kashif*[1], *Muhammad Dilshad*[2]**
[1]Department of Entomology, FA&E, The Islamia University of Bahawalpur, 63100, Bahawalpur, Pakistan
[2]Faculty of Agricultural Sciences and Technology, University of Agriculture Faisalabad 38000, Faisalabad, Pakistan
***Corresponding Author's email address:** chismailyasin@gmail.com

Article Info

Keywords:
Castor oil, Thiamethoxam, propiconazole, *Coccinella septempunctata*, Biosafety
Date:
Received: 19 June 2025
Accepted: 20 July 2025
Published: 15 December 2025

Volume: 04 (01), 2025

Copyright: © 2025 by the authors. This article is distributed under the Creative Commons Attribution (CC BY) license, allowing for open access and sharing under specified terms and conditions. (https://creativecommons.org/licenses/by/4.0/).

Abstract

This study investigates the comparative biosafety of neem extract, castor oil, thiamethoxam, and propiconazole against the seven-spotted ladybird beetle, *Coccinella septempunctata*, through three distinct application methods: topical, dietary, and residual methods. Adult *C. septempunctata* were reared under controlled conditions and exposed to five different concentrations of each treatment over a ten-day period. The study utilized a Complete Randomized Design (CRD) with three replications for precise evaluation. The biosafety of treatments was measured by monitoring mortality rates and comparing the effects of synthetic pesticides (thiamethoxam and propiconazole) and biopesticides (neem extract and castor oil) on *C. septempunctata*. The results revealed that synthetic pesticides exhibited significantly higher mortality rates compared to biopesticides. In contrast, neem extract and castor oil showed lower and more variable mortality rates, indicating their relatively safer profile for beneficial insects. The study's findings highlight the effectiveness of synthetic pesticides in pest control but also underscore their potential risks to non-target beneficial species. Conversely, biopesticides, while less lethal, offer a more sustainable approach for IPM by mitigating harm to beneficial insects. The results emphasize the need for careful selection of pest control methods to balance efficacy with environmental safety in agricultural practices.

1. Introduction

The seven-spotted ladybird beetle (*Coccinella septempunctata* L.) is a well-known and widely distributed species of lady beetles. It originated in Europe and Asia and has since spread to North America and other parts of the world as a natural pest control agent. The adult beetles are usually 7-10 mm long and can be identified by their brilliant red or orange elytra, having seven black dots on them. (Honěk et al., 2023). As a polyphagous insect, *C. septempunctata* feeds on a wide range of insect pests, including members of the Aphidoidea, Psylloidea, and Coccoidea families as well as Tetranychidae, which infest crops in both greenhouses and open fields and make it an effective biological control agent moreover in case of prey shortage it can sustain on pollen and honeydew to some extent. (Lu et al., 2012; Hodek and Michaud, 2013; Farooq et al., 2020). The life cycle of *C. septempunctata* consists of four stages: egg, larva, pupa and adult, with four larval instars and three molting stages. The third and fourth instar larvae are particularly voracious, making them highly effective predators during these stages (Atta et al., 2019).

Coccinella septempunctata can reproduce numerous times per year, with adults hibernating in the winter months, allowing for consistent pest control throughout the sprouting season (Saleem et al., 2014). The omnivorous behavior makes *C. septempunctata* an effective natural competitor for extensive pest control. Additionally, *C. septempunctata* serves as an ideal model organism for assessing the negative impacts of pesticides on non-target

Corresponding Author: Muhammad Ismail Email: chismailyasin@gmail.com

natural enemies, aiding in the development of targeted conservation strategies (Wu et al., 2021).

In many crops such as cotton, wheat, ornamental plants and in vegetables and fruits, neonicotinoid insecticides are the most commonly employed for suppressing aphid population and other notorious insect pests because of their systemic action, numerous administration methods, high efficiency and stability. Thiamethoxam is an insecticide that belongs to the neonicotinoid group and is commonly used in agriculture. It is used as a spray, drench, or seed treatment to manage a variety of insect pests, such as aphids and other sap feeders (North et al., 2016; Krupke et al., 2017). Thiamethoxam and its active metabolites largely travel through the xylem after application, but there is also phloem translocation (Bonmatin et al., 2015). Previous research indicates that thiamethoxam is very mobile throughout the plants parts therefore it can interfere with biological control agents, especially when predatory natural enemies like lady beetles consume prey that has pesticide residues on it as well as in their body fluids entering through dietary exposure (Douglas et al., 2015). According to empirical data, thiamethoxam can continue to be reactive against targeted pests for five to twenty-five days after sprays (Esquivel et al., 2019).

By adopting IPM strategies, farmers can minimize the negative impacts of pesticides on beneficial insects and promote a healthier ecosystem (Naranjo et al., 2015). Biological control using the seven-spotted ladybird beetle is a crucial strategy in pest management, aimed at maximizing pest control while minimizing the need for insecticidal sprays. This strategy involves conserving existing beetle populations, artificially rearing them, and releasing them augmentatively into the environment. As a generalist predator, *C. septempunctata* is highly valued in countries such as China and Pakistan (Zhang et al., 2011; Zada et al., 2012). The beetle's importance as a bio-control agent is further enhanced by its ability to respond to olfactory cues from aphid prey, allowing it to effectively locate and prey upon different aphid species (Yu et al., 2022). However, non-target beneficial arthropods like coccinellids are at risk from pesticide exposure, which can affect them directly or through contact with residues on treated surfaces (He et al., 2012; Yao et al., 2015). Insecticides pose significant lethal and sublethal threats to various coccinellid species, including *C. septempunctata* (Depalo et al., 2017).

Sublethal effects can impact a wide range of physiological and behavioral traits, including development time, longevity, fecundity, and fertility (Moscardini et al., 2015). For example, the insect growth regulator hexaflumuron has been shown to negatively affect *C. septempunctata* development, survival, pupation, and hatching rates, while sublethal doses of imidacloprid can reduce egg production, potentially leading to population declines (Yu et al., 2014; Xiao et al., 2016).

Bio-insecticides often contain secondary metabolites that act as repellents, growth regulators, and deterrents, affecting insect behavior and development (Zanuncio et al., 2016). Neem oil, derived from *Azadirachta indica*, is a well-known bio-insecticide with insecticidal properties against various pests, including those in the Coleoptera, Hemiptera, and Lepidoptera orders (Yasmin et al., 2008). Following objectives were covered in the current study. To evaluate and compare the negative impact of neem oil, castor oil, thiamethoxam, and propiconazole on *C. septempunctata* adult and relative safety or toxicity of selective pesticides to *C. septempunctata*.

.

2. Materials and Methods

3.1. Experimental site

This investigation was undertaken at the Entomology Laboratory, Faculty of Agriculture, The Islamia University of Bahawalpur, located in a region characterized by a homogeneous topography and an elevation of 214 meters above sea level. The laboratory's precise geospatial coordinates are 29°25'5.00448" N latitude and 71°40'14.660" E longitude. All experimental protocols and observational procedures were meticulously executed under optimum environmental controls, ensuring a consistent and stable experimental setting throughout the duration of the study.

3.2. Insect collection and rearing methodology

Adult *C. septempunctata* were sourced from an insecticide-free wheat field within the university's research area in Bahawalpur. The collected specimens were then reared on aphid-infested mustard (*Brassica juncea*) twigs under controlled laboratory conditions, ensuring optimal survival and development. The rearing environment was thoroughly maintained at 25±1°C, 50±10% relative humidity, and a 14:10 light-dark photoperiod. The experimental design employed a Complete Randomized Design (CRD) with three replications, ensuring reliable and reproducible results. This design enabled the precise evaluation of treatment effects while controlling for extraneous variables, thereby enhancing the validity and reliability of the findings.

3.3. Preparation of biopesticides and insecticide solutions

Five treatments were prepared, comprising two botanical insecticides (castor oil and neem oil) and two synthetic chemicals (Thiamethoxam and Propiconazole), for bioassays against the ladybird beetle (*C. septempunctata*).

©PagePal. All Rights Reserved.

3.4. Bioassay

A bioassay was conducted to evaluate the efficacy of various treatments against the 7-spotted ladybird beetle (*C. septempunctata*). The treatments consisted of: neem extract (5 ppm), castor oil (5 ppm), thiamethoxam (2 ppm) and propiconazol (2 ppm), with a control treatment. Each treatment was replicated three times, with 20 adult beetles freshly emerged from pupae were used in each replication. The treatments were applied using three different methods: film residues, dietary incorporation, and direct application on insects. The insecticide, fungicide, and botanical extract were prepared in water and mixed into an artificial diet using a hand shake. The artificial diet was prepared by individually weighing the ingredients listed in Table 1**.**

Distilled water and egg yolk were combined and heated in a microwave oven before being completely blended with an electric blender to obtain a uniform, semi-solid consistency. The diet was kept at -5°C in refrigerator.

2.5 Topical application

Topical application is a frequently used technique in which an operated micro applicator applies the pesticide and plant extract produced in distilled water, measured droplets, to a selected spot on the body surface on thorax of experimented insect. There is a precision syringe with a micrometer-driven motor and a topical applicator. The advantages of this approach include the high degree of precision and reproducibility that can be attained, the ability to complete a large number of tests in a short amount of time, the requirement for only 10-20 insects per replication, the ease of use and low cost of the equipment, and the minimal use of toxicants and solvents. In this method, first of all, 2ppm solutions of thiamethoxam and propiconzaol and 5ppm solutions of botanical extracts (Neem oil and castor oil) were prepared. These solutions have been applied on thorax of insect by micro applicator in controlled laboratory conditions. The insects were kept in petri dishes and served fresh aphids on daily bases until experiment ended and data was recorded.

2.6 Contact or residual method

This approach involves coating a glass vial with the insecticide solution after diluting the prepared pesticide in distilled water, a solvent. By turning the container, the solvent is allowed to evaporate, distributing the insecticide uniformly across the whole surface and leaving behind a residual coating. When insects were released on a treated surface, they come into contact with leftover film. In this method the 2ppm solutions of thiamethoxam and propiconazol and 5ppm solution of botanical extracts (neem oil and castor oil) were prepared. The glass petri dishes were dipped with these solutions. After air drying the petri dishes, the insect were released in these petri dishes under controlled laboratory conditions. Aphids were served as food for ladybird beetle during the course of experiments on daily bases. The data was recorded.

Table 1: Ingredients of artificial diet

Sr.#	Ingredient	Diet weight
1.	Beef	15g
2.	Beef liver	15g
3.	Egg yolk	15g
4.	Honey	3g
5.	Sucrose	5g
6.	Infant formula	300mg
7.	Olive oil	100µl
8.	Distilled water	40ml

2.7 Diet exposure method

The artificial diet was prepared with following ingredients given in Table1. All the ingredients were thoroughly blended in an electric blender until semi-liquid consistency. The solutions of 2ppm thiamethoxam and propiconazol and 5ppm solutions of botanical extracts (neem oil and castor oil) were mixed with artificial diets separately and artificial diet without insecticides were served in control group. Twenty freshly emerged lady bird beetles adults were placed in each petri dish with drop of artificial diet in each treatments. The diet in each treatment was replaced on daily bases. The mortality data was recorded in each treatments.

2.8 Data collection

The beetles were subjected to continuous exposure for a period of 10 days, during which the number of mortalities was observed and recorded consecutively at 03, 07 and 10 days intervals. The cumulative number of dead and live insects was accurately counted and documented at each designated time point, providing a comprehensive record of mortality and survival rates over the 10-days observation period.

2.9 Data Analysis and statistical evaluation

The corrected mortality percentage was determined using Abbot's formula (1925):

$$\text{Corrected mortality}=\left(1-\frac{n\ numer\ of\ T\ treatments}{n\ number\ of\ Co\ treatments}\right)\times 100$$

Where

n= insect population

T= treated

Co=control

©PagePal. All Rights Reserved.

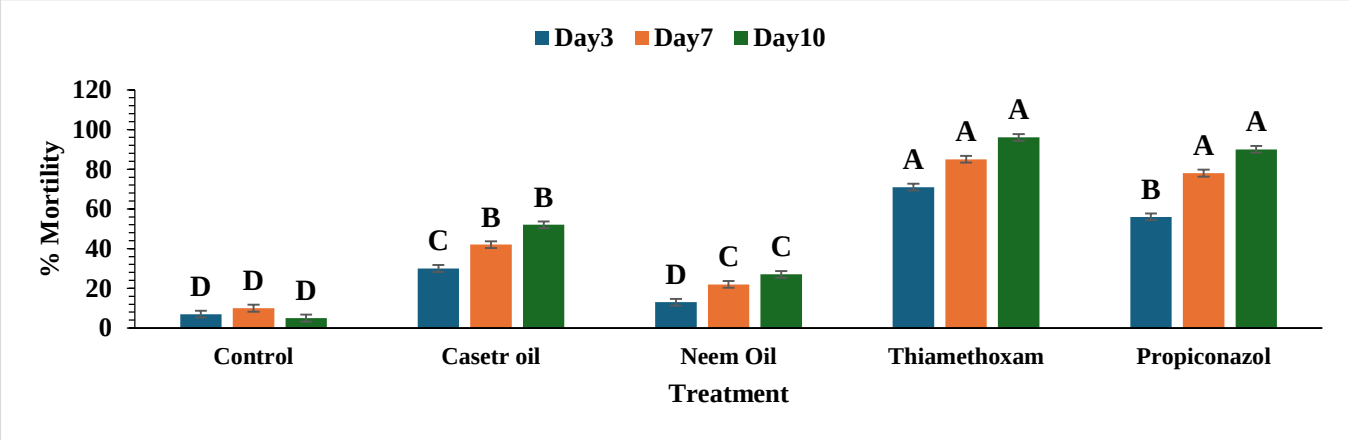
Table2. Analysis of variance table for topical application method

Sources of Variations	DF	SS	MS	*F*	*P*
Replication	2	270	135		
Treatment	4	39812.8	9953.2	15083.5	≤0.00
Time	2	2667.6	1333.8	1902.15	≤0.00
Treatment × Time	8	1126.4	140.8	223.71	≤0.00
Error	28	16.5	0.59	-	-
Total	44	43876.8	-	-	-

Table 3. Analysis of variance table for dietary exposure method

Sources of Variations	DF	SS	MS	F	P
Replication	2	333.5	166.76		
Treatment	4	35530.1	8882.52	15083.5	≤0.00
Time	2	2240.3	1120.16	1902.15	≤0.00
Treatment × Time	8	1053.9	131.74	223.71	≤0.00
Error	28	16.5	0.59	-	-
Total	44	39174.3	-	-	-

Figure 1: Mortality rates of *C. septempunctata* after topical application of pesticides. The similar letter indicates results are significantly similar while dissimilar characters shows significantly different results



To effectively compares the effects of bio pesticides versus synthetic pesticides and determine their statistical significance. This approach will help clarify how each pesticide type impacts the mortality of the 7 spotted ladybird beetle, specifically under the method of application via residual film sheets, dietary exposure and topical method. Assuming a typical analytical approach, an ANOVA followed by Tukey's HSD was used to determine if differences in mortality rates between treatments are statistically significant. A p-value of <0.05 would generally be considered to indicate significant differences.

3. Results

3.1 Topical method

The application of bio-pesticides and synthetic pesticides through topical methods reveals notable differences in their effects on *C. septempunctata*. The mean mortality rates, averaged across the treatment periods, highlight these disparities. The mean mortality rates for *C. septempunctata* exposed to neem oil range from 13% to 27% at the day 3 to 10 respectively. Castor oil results in a mean mortality rate between 30% and 52%. The effectiveness of castor oil

Table 4. Analysis of variance table for sheet film residual bioassay

Sources of Variations	DF	SS	MS	F	P
Replication	2	307.2	153.6		
Treatment	4	27657.2	6914.3	22000	0.00
Time	2	1450.8	725.4	2308.09	0.00
Treatment × Time	8	563.2	70.4	224	0.00
Error	28	8.8	0.31	-	-
Total	44	29987.2	-	-	-

varies considerably, with some treatments causing higher mortality, particularly during intermediate stages of exposure. This synthetic pesticide produces a mean mortality rate ranging from 71% to 96%. Thiamethoxam is observed to be highly fatal to *C. septempunctata*, especially with the passage of time. The mean mortality rates for propiconazole range from 56% to 90% (Figure 1).

©PagePal. All Rights Reserved.

Figure 2: Mortality Rates of *C. septempunctata* after Dietary Exposure of pesticides. The similar letter indicates results are significantly similar while dissimilar characters shows significantly different results.

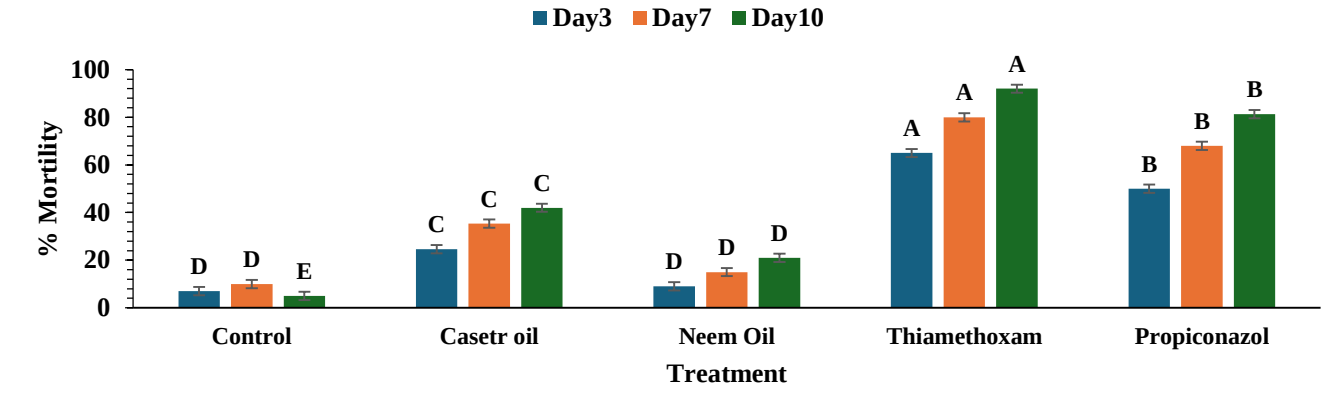
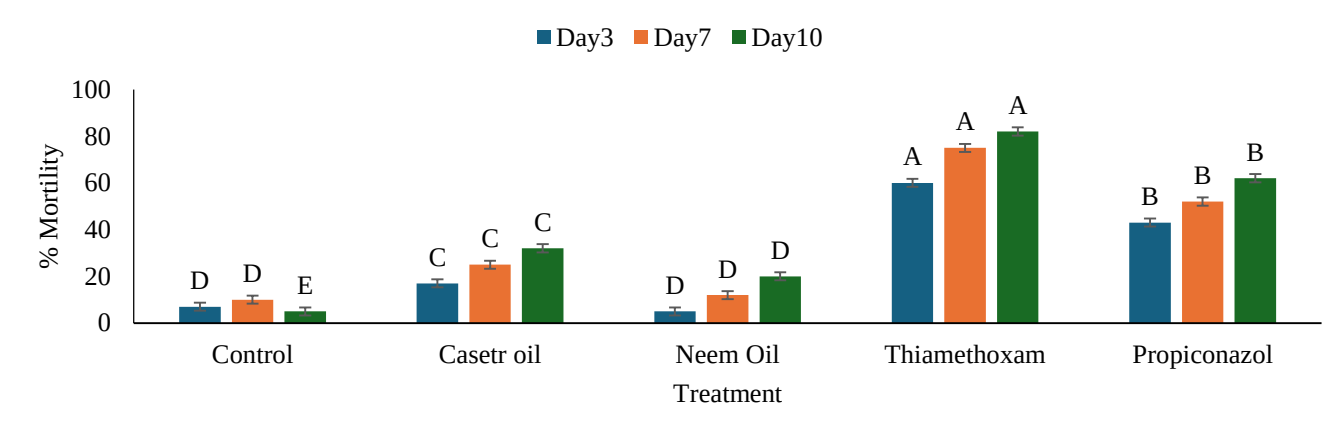


Figure 3: Mortality Rates of *C. septempunctata* after Sheet Film Residue of pesticides. The similar letter indicates results are significantly similar while dissimilar characters shows significantly different results.



Statistical analysis reveals significant differences between synthetic pesticides (thiamethoxam & propiconazole) and biopesticides (neem oil & castor oil) in terms of mortality rates (Table 1). Synthetic pesticides generally exhibit higher and more immediate impacts on mortality of *C. septempunctata*, compared to the more moderate and variable effects of bio pesticides.

3.2 Dietary exposure method

The ten-day exposure study on *C. septempunctata* using various insecticides incorporated into an artificial diet reveals marked differences in mortality rates across treatments. The mean mortality rates for *C. septempunctata* exposed to neem oil range from 9% to 21%. This trend indicates a moderate impact on *C. septempunctata*, though it is less consistent in its lethality compared to synthetic pesticides. Exposure to castor oil results in mean mortality rates ranging between 24.66% and 42%. Most treatments lead to minimal mortality, with a significant increase in effectiveness observed only at treatment 3. Overall, castor oil is considerably less toxic to *C. septempunctata* compared to the synthetic pesticides tested. The synthetic pesticide thiamethoxam produces a mean mortality rate from 65% to 92%. It exhibits a strong initial impact with substantial lethality, particularly noticeable during the early stages of exposure. Similar to thiamethoxam, propiconazole results in mean mortality rates, ranging from 50% to 81.33%. In control, which received no insecticide treatment, shows minimal mortality rates ranging from 7% to 5%. This low mortality confirms that the observed effects are attributable to the insecticides rather than other factors.

The study highlights significant differences between synthetic pesticides and biopesticides in their impact on *C. septempunctata*. Synthetic pesticides such as thiamethoxam and propiconazole result in substantially higher mortality rates, underscoring their potent effects and potential risks to beneficial insect populations. In contrast, biopesticides like

©PagePal. All Rights Reserved.

neem oil and castor oil exhibit lower and more variable mortality rates. Castor oil, in particular, demonstrates a safer profile for *C. septempunctata*. These findings suggest that while synthetic pesticides are highly effective, their use poses significant risks to beneficial insects. Bio pesticides, with their lower lethality and variability, offer a more sustainable alternative for pest management, aiming to balance pest control with the conservation of beneficial insect populations.

3.3 Film residual method

The sheet film residual method, conducted over ten consecutive days, provides a detailed assessment of the impact of various insecticides on *C. septempunctata*. The results highlight significant differences in mortality rates among the treatments, with implications for their relative toxicity.

Neem oil exhibited mean mortality rates ranging from 7% to 20%. The highest mortality was observed on day 10, reaching 20%. This indicates a moderate level of toxicity with a clear reduction in impact over time. Statistical analysis shows that the mortality rates for neem oil are significantly different from the control group ($p < 0.05$), though it remains less harmful compared to synthetic pesticides. Castor Oil demonstrated a mean mortality range between 17% and 32%. A significant spike in mortality occurred on Day 10 (32%). This variability in mortality suggests that castor oil has a less consistent effect, with high variability in its impact. The mortality rates for castor oil also significantly differ from the control group ($p < 0.05$), though overall, it is less toxic than synthetic options. Propiconazole resulted in mean mortality rates ranging from 43% to 62%. Thiamethoxam showed mean mortality rates from 60% to 82%. The peak mortality rate was observed on day 10 at 82%. Thiamethoxam exhibited a marked initial impact, with significant mortality observed throughout most of the exposure period. The mortality rates for Thiamethoxam are significantly different from those of the control group ($p < 0.05$), highlighting its substantial toxicity. Control receiving no insecticide treatment, displayed minimal mortality rates ranging from 5% to 7%. This low level of mortality confirms that the insecticides are responsible for the observed effects in the treated groups.

The sheet film residual method reveals that synthetic pesticides (thiamethoxam and propiconazole) have a higher and more immediate impact on *C. septempunctata*, with significantly higher mortality rates compared to bio pesticides. Bio pesticides such as neem oil and castor oil show lower and more variable mortality rates, indicating they are less harmful to beneficial insects. The significant differences ($p < 0.05$) in mortality rates confirm that synthetic pesticides are more detrimental to *C. septempunctata* compared to the bio pesticides assessed.

4. Discussion

The comparative analysis of insecticidal safety against *C. septempunctata*, a vital predatory insect in agricultural ecosystems is essential for understanding the environmental implications of using both synthetic and biopesticides.

The study's findings underscore the pronounced toxicity of synthetic pesticides, particularly thiamethoxam and propiconazole, in causing significant mortality in *C. septempunctata*. Thiamethoxam, a widely recognized neonicotinoid, exerts its lethal effects by targeting the insect nervous system, specifically binding to nicotinic acetylcholine receptors, which leads to paralysis and eventual death (Jeschke et al., 2011). This mechanism, coupled with its systemic nature, ensures that thiamethoxam remains active within plant tissues, making it a formidable insecticide against herbivorous pests (Elbert et al., 2008). Similarly, propiconazole, though primarily a fungicide, has demonstrated insecticidal properties by disrupting cell membrane synthesis in insects, contributing to its detrimental impacts against *C. septempunctata*. The high initial mortality rates observed in the topical application method up to 96% for thiamethoxam and 90% for propiconazole highlight the potent and immediate impact of these chemicals on non-target beneficial insects (Khan et al., 2020; Patel and Patel, 2019). This immediate lethality can be crucial in scenarios that demand rapid pest control, yet it also raises significant concerns about the potential risks posed to beneficial insect populations and overall ecological balance (Pisa et al., 2015).

In addition to their immediate efficacy, the persistence of thiamethoxam and propiconazole contributes significantly to their long-term impact. The sheet film residual method demonstrated that both pesticides maintained high mortality rates over time, particularly in the initial days post-application, with thiamethoxam showing mean mortality values of 82% and propiconazole 62% on Day 10 (Zhao et al., 2023). Studies have highlighted that the persistence of neonicotinoids like thiamethoxam in the environment can lead to prolonged exposure for beneficial insects, increasing the likelihood of adverse effects (Sánchez-Bayo and Goka, 2014). While this persistence ensures sustained pest control, it also presents environmental challenges, such as the risk of bioaccumulation and prolonged exposure to non-target organisms (Goulson, 2013). Neonicotinoids like thiamethoxam are known to persist in soil and water, leading to long-term exposure risks for beneficial insects, including pollinators and predators like *C. septempunctata* (Bonmatin et al., 2015; Pisa et al., 2015).

Thiamethoxam's high mortality rates in the dietary exposure method, reaching up to 92%, highlight its potent systemic action, where the insecticide remains active within plant tissues, posing a persistent threat to herbivorous

©PagePal. All Rights Reserved.

insects feeding on treated plants (Saeed et al., 2021; Elbert et al., 2008). Propiconazole also demonstrated significant mortality, though less aggressive than thiamethoxam, reflecting a less intense but still considerable impact. The dietary exposure method is crucial for evaluating the long-term risks associated with systemic insecticides, as these chemicals can persist in plant tissues, continuously endangering non-target insects long after the initial application. The sustained high mortality observed with thiamethoxam raises serious concerns about the potential risks to beneficial insects, such as *C. septempunctata*, which may suffer not only from direct toxicity but also from sub-lethal effects like reduced fecundity and impaired foraging behaviour, further amplifying the detrimental impacts on insect populations (Godfray et al., 2014).

In contrast to synthetic pesticides, neem oil and castor oil exhibited lower and more variable mortality rates against *C. septempunctata*. Neem oil, derived from the seeds of *Azadirachta indica*, and castor oil, obtained from the seeds of *Ricinus communis*, demonstrated lower and more variable mortality rates against *C. septempunctata* compared to synthetic pesticides. Neem oil's effectiveness, particularly in the dietary exposure method, diminished over time, with efficacy declining significantly after initial application (Khan *et al.*, 2022). This reduced effectiveness can be attributed to the mode of action of neem oil, which disrupts hormonal systems in insects, leading to growth inhibition and reproductive failure rather than immediate lethality (Isman, 2006; Mordue and Nisbet, 2000). Additionally, environmental factors such as UV degradation and volatility may contribute to the decreased persistence of neem oil, further limiting its efficacy. Castor oil, in contrast, exhibited minimal toxicity overall, with inconsistent results across different application methods (Khan et al., 2020). The insecticidal properties of castor oil are primarily due to its ability to create a physical barrier on insect exoskeletons, leading to desiccation and suffocation (Salatino et al., 2007). However, this mode of action is less effective against mobile insects like *C. septempunctata*, resulting in variable mortality rates.

Despite their lower efficacy, neem oil and castor oil present significant environmental advantages, making them viable components of integrated pest management (IPM) strategies. Both biopesticides are biodegradable and pose minimal risks to non-target organisms, aligning with the goals of IPM, which aim to control pest populations while minimizing environmental impact. Neem oil, in particular, has demonstrated a repellent effect on a wide range of pests while being less harmful to beneficial insects. However, the variability in efficacy observed in this study underscores the need for optimization of biopesticides formulations and application methods to enhance their effectiveness (Dubey et al., 2010). As such, while biopesticides like neem oil and castor oil offer a safer alternative to synthetic pesticides, their use in IPM programs requires careful consideration and further refinement to maximize their potential benefits (Ghisalberti, 1999; Adebowale and Adedire, 2006).

The differential impact of synthetic and biopesticides on *C. septempunctata*, a beneficial predator essential for controlling aphid populations, has critical implications for pest management practices. The high mortality rates observed with synthetic pesticides like thiamethoxam and propiconazole raise significant concerns about their non-selective nature, which can harm beneficial insects and disrupt ecological balance (Goulson, 2013). Thiamethoxam, a neonicotinoid, is known for its systemic action, leading to prolonged toxicity and potential bioaccumulation, which can severely impact non-target species like *C. septempunctata*. Propiconazole, primarily a fungicide with insecticidal properties, also demonstrated significant lethality, further highlighting the risks associated with the use of synthetic chemicals in pest management (Zhao et al., 2013). The disruption of beneficial insect populations caused by these synthetic pesticides can lead to secondary pest outbreaks, necessitating further chemical interventions and creating a cycle of dependency that undermines sustainable agricultural practices (Van der Sluijs et al., 2013).

In contrast, biopesticides such as neem oil and castor oil offer a more environmentally friendly alternative with lower toxicity to non-target organisms. Neem oil, derived from the seeds of *Azadirachta indica*, operates through hormonal disruption, leading to growth inhibition and reproductive failure in pests rather than immediate lethality (Isman, 2006). This mode of action, while less aggressive than synthetic pesticides, aligns more closely with the principles of integrated pest management (IPM), which seeks to preserve natural enemies of pests while effectively controlling pest populations. Castor oil, obtained from the seeds of Ricinus communis, primarily exerts its insecticidal effects through physical mechanisms, such as suffocation, which, while less effective against mobile insects, further reduces the risk of harm to beneficial species (Salatino et al., 2007). The lower toxicity and reduced environmental persistence of these biopesticides make them valuable components of IPM strategies aimed at balancing pest control with the conservation of biodiversity (Copping and Menn, 2000).

Despite their advantages, the variable efficacy of biopesticides poses challenges for their widespread adoption in IPM programs. Neem oil's effectiveness, for instance, has been shown to diminish over time, particularly in the dietary exposure method, which may be due to environmental factors such as UV degradation. Castor oil, with its minimal and inconsistent toxicity, also highlights the need for

©PagePal. All Rights Reserved.

optimization in biopesticide formulations and application methods to enhance their reliability (Adebowale and Adedire, 2006). Recent research emphasizes the importance of improving the stability, concentration, and delivery systems of biopesticides to increase their efficacy, ensuring they can be viable alternatives to synthetic chemicals in sustainable agriculture. Moreover, integrating biopesticides with other control methods, such as biological agents or cultural practices, could provide a more comprehensive and robust approach to pest management within an IPM framework (Chandler et al., 2011).

The ecological implications of relying heavily on synthetic pesticides are profound, particularly in agricultural systems dependent on beneficial insects like *C. septempunctata* for natural pest control. The decline of these beneficial populations due to synthetic pesticide use not only increases the risk of secondary pest outbreaks but also threatens ecosystem services such as pollination and soil health, which are vital for agricultural productivity and biodiversity (Potts et al., 2010). Biopesticides, with their lower environmental impact and potential for biodegradability, offer a promising alternative that aligns with the goals of sustainable agriculture. However, to fully realize their potential, ongoing research and development are necessary to address their current limitations and to integrate them effectively into IPM strategies that minimize environmental harm while maintaining agricultural productivity.

In conclusion, the comparative analysis of insecticide application methods reveals significant differences in the impact of synthetic and biopesticides on *C. septempunctata*. Synthetic pesticides, particularly thiamethoxam and propiconazole, demonstrated higher mortality rates across all methods, reflecting their potent immediate impact and persistent effects. However, the high toxicity of these chemicals raises concerns about their potential risks to beneficial insects and the broader ecological consequences of their use. In contrast, biopesticides like neem oil and castor oil exhibited lower toxicity, making them more suitable for use in IPM programs that aim to preserve ecological balance. The findings underscore the need for further research to optimize the use of biopesticides and develop sustainable pest management strategies that minimize the environmental impact of agricultural practices.

5. Conclusion

The results of this study emphasize the critical importance of selecting insecticides that balance effectiveness with environmental safety, particularly regarding the preservation and conservation of beneficial insect populations like *C. septempunctata*. Synthetic pesticides, such as thiamethoxam demonstrated significantly higher mortality rates across all application methods, posing substantial risks to non-target species and potentially leading to broader ecological disruptions. These findings highlight the immediate potency and prolonged persistence of synthetic chemicals, which, while effective in pest control, can undermine the sustainability of agricultural ecosystems by threatening beneficial insect populations. In contrast, biopesticides like neem oil and castor oil, though less effective in terms of immediate mortality, offer a safer alternative that aligns more closely with the goals of sustainable agriculture and Integrated Pest Management (IPM). These natural alternatives caused considerably lower mortality rates in *C. septempunctata*, indicating their potential to minimize environmental harm while still contributing to pest control efforts. The study supports the integration of biopesticides into IPM strategies, where their use can help in conserving beneficial insect populations and maintain ecological balance. Overall, the findings advocate for a more cautious and balanced approach to pest management, one that prioritizes the long-term sustainability of agricultural practices. Future research should focus on optimizing the formulations and application methods of biopesticides to enhance their efficacy, as well as exploring their synergistic use with other pest control strategies. By doing so, it may be possible to achieve effective pest control while minimizing the adverse effects on beneficial insect populations along with safe and sustainable environment.

6. Funding

No funding was received for this study.

6. Acknowledgment

The authors are grateful to the Syngenta, Pakistan and Sawat Agro chemicals Private Ltd. for providing insecticides.

7. Conflict of Interest

The authors declare no conflict of interest.

8. Authors' Contribution

MI designed the study and conducted bioassay
MA helped in collecting data and provided guidelines on bioassay setting and proof read the MS
RJ performed statistical analysis and prepared data tables
MW completed write up and finalized the MS
MK Proof read the document and **p**repared tables and figures
MD help in collecting and rearing population and crop plantation and logistic sport

References

Adebowale, K. O., & Adedire, C. O. (2006). Chemical composition and insecticidal properties of the underutilized *Jatropha curcas* seed oil. *African Journal of Biotechnology*, *5*(10), 901-906.

©PagePal. All Rights Reserved.

Atta, B., Rizwan, M., Sabir, A. M., Ayub, M. A., Akhtar, M. F., Ayyub, M. B., & Nadeem, S. (2019). Comparative incidence and abundance of aphids and their associated predators on canola in Pakistan. *Pakistan Entomologist*, *41*(2), 12-25.

Bonmatin, J. M., Giorio, C., Girolami, V., Goulson, D., Kreutzweiser, D. P., Krupke, C., & Tapparo, A. (2015). Environmental fate and exposure; neonicotinoids and fipronil. *Environmental Science and Pollution Research*, 22(1), 35-67.

Bonmatin, J. M., Giorio, C., Girolami, V., Goulson, D., Kreutzweiser, D. P., Krupke, C., & Tapparo, A. (2015). Environmental fate and exposure; neonicotinoids and fipronil. *Environmental Science and Pollution Research*, *22*, 35-67.

Chandler, D., Bailey, A. S., Tatchell, G. M., Davidson, G., Greaves, J., & Grant, W. P. (2011). The development, regulation and use of biopesticides for integrated pest management. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1573), 1987-1998.

Copping, L. G., & Menn, J. J. (2000). Biopesticides: a review of their action, applications and efficacy. *Pesticide Management Science: formerly Pesticide Science*, *56*(8), 651-676

Depalo, L., Lanzoni, A., Masetti, A., Pasqualini, E., & Burgio, G. (2017). Lethal and sub-lethal effects of four insecticides on the aphidophagous coccinellid *0* (Coleoptera: Coccinellidae). *Journal of economic entomology*, *110*(6), 2662-2671.

Douglas, M. R., Rohr, J. R., & Tooker, J. F. (2015). Neonicotinoid insecticide travels through a soil food chain, disrupting biological control of non-target pests and decreasing soya bean yield. *Journal of applied ecology*, *52*(1), 250-260.

Dubey, N. K., Shukla, R., Kumar, A., Singh, P., & Prakash, B. (2010). Prospects of botanical pesticides in sustainable agriculture. *Current Science*, *98*(4), 479-480.

Elbert, A., Haas, M., Springer, B., Thielert, W., & Nauen, R. (2008). Applied aspects of neonicotinoid uses in crop protection. Pest Management Science: formerly Pesticide *Science*, *64*(11), 1099-1105.

Esquivel, C. J., Ranger, C. M., Phelan, P. L., Martinez, E. J., Hendrix, W. H., Canas, L. A., & Michel, A. P. (2019). Weekly survivorship curves of soybean aphid biotypes 1 and 4 on insecticidal seed-treated soybean. *Journal of economic entomology*, *112*(2), 712-719.

Farooq, M., Zhu, X., Shakeel, M., Iftikhar, A., Shahid, M. R., Saeed, N., & Arain, M. S. (2020). Comparative analysis of the demographic parameters of seven spotted ladybird beetle (Coleoptera: Coccinellidae) reared on various host aphid species. *PeerJ*, *8*, e8313.

Ghisalberti, E. L. (1999). Castor oil and its constituents. *Planta Medica*, *65*(04), 307-310.

Godfray, H. C. J., Blacquière, T., Field, L. M., Hails, R. S., Petrokofsky, G., Potts, S. G., & McLean, A. R. (2014). A restatement of recent advances in the natural science evidence base concerning neonicotinoid insecticides and insect pollinators. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1786), 20140558.

Goulson, D. (2013). An overview of the environmental risks posed by neonicotinoid insecticides. *Journal of Applied Ecology*, *50*(4), 977-987.

He, Y., Zhao, J., Zheng, Y., Desneux, N., & Wu, K. (2012). Lethal effect of imidacloprid on the coccinellid predator *Serangium japonicum* and sublethal effects on predator voracity and on functional response to the whitefly *Bemisia tabaci*. *Ecotoxicology*, *21*, 1291-1300.

Hodek, I., & Michaud, J. P. (2013). Why is *Coccinella septempunctata* so successful? (A point-of-view). *EJE*, *105*(1), 1-12.

Honěk, A., Novák, I., Martinková, Z., Saska, P., Kulfan, J., Holecová, M., & Zach, P. (2023). Trophic Ecology Drives Annual Variation in Abundance of Aphidophagous (Coccinellidae, Coleoptera and Chrysopidae, Neuroptera) and Phytophagous (Noctuidae, Lepidoptera) Insects: Evidence from Light Traps. *Annals of the Entomological Society of America*, *116*(2), 125-140.

Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual review of entomology*, *51*, 45-66.

Jeschke, P., Nauen, R., & Schindler, M. (2011). Overview of the status and global strategy for neonicotinoids. Insecticide design and discovery: importance of synthetic methodologies. *ACS Symposium Series*, 1072, 17-42.

Khan, M. F., Ali, S., & Mahmood, T. (2020). Effects of neem oil and synthetic pesticides on beneficial insects in integrated pest management. *Journal of Pest Science*, *93*(1), 159-168.

Khan, M., Afzal, A., & Khalil, S. K. (2020). Effect of thiamethoxam on mortality of *Coccinella septempunctata*. *International Journal of Agriculture and Biology*, *22*(4), 832-836.

Khan, S., Afzal, S., & Ahmed, M. (2022). Evaluation of neem oil efficacy against different pests. *Journal of Agricultural Research*, *60*(3), 402-408.

Krupke, C. H., Alford, A. M., Cullen, E. M., Hodgson, E. W., Knodel, J. J., McCornack, B., & Welch, K.

©PagePal. All Rights Reserved.

(2017). Assessing the value and pest management window provided by neonicotinoid seed treatments for management of soybean aphid (*Aphis glycines* Matsumura) in the Upper Midwestern United States. *Pest management science*, *73*(10), 2184-2193.

Lu, Y., Wu, K., Jiang, Y., Guo, Y., & Desneux, N. (2012). Widespread adoption of Bt cotton and insecticide decrease promotes biocontrol services. *Nature*, *487*(7407), 362-365.

Mordue, A. J., & Nisbet, A. J. (2000). Azadirachtin from the neem tree *Azadirachta indica*: its action against insects. *Anais da Sociedade* Entomol *gica do* Brasil, 29(4), 615-632.

Moscardini, V. F., Gontijo, P. C., Michaud, J. P., & Carvalho, G. A. (2015). Sublethal effects of insecticide seed treatments on two Nearctic lady beetles (Coleoptera: Coccinellidae). *Ecotoxicology*, *24*, 1152-1161.

Naranjo, S. E., Ellsworth, P. C., & Frisvold, G. B. (2015). Economic value of biological control in integrated pest management of managed plant systems. *Annual review of entomology*, *60*, 621-645.

North, J. H., Gore, J., Catchot, A. L., Stewart, S. D., Lorenz, G. M., Musser, F. R., & Dodds, D. M. (2016). Value of neonicotinoid insecticide seed treatments in mid-south soybean (Glycine max) production systems. *Journal of economic entomology*, *109*(3), 1156-1160.

Patel, P. S., & Patel, R. K. (2019). Comparative analysis of neem oil and synthetic pesticides: A review. *Pest Management Science*, *75*(10), 2625-2634.

Pisa, L. W., Amaral-Rogers, V., Belzunces, L. P., Bonmatin, J. M., Downs, C. A., Goulson, D., & Simon-Delso, N. (2015). Effects of neonicotinoids and fipronil on non-target invertebrates. *Environmental Science and Pollution Research*, 22, 68-102.

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and. Evolution*, *25*(6), 345-353.

Saeed, S., Khan, S., & Farooq, M. (2021). The role of biopesticides in sustainable agriculture: A review of their impact on non-target organisms. *Biopesticides International*, *17*(1), 35-47.

Sahayaraj, K., & Hassan, E. (2023). Biocompatibility of Biopesticides with Predatory Insects. In *Worldwide Predatory Insects in Agroecosystems* (pp. 785-820). Singapore: Springer Nature Singapore.

Salatino, A., Salatino, M. L. F., & Negri, G. (2007). Traditional uses, chemistry and pharmacology of Croton species (Euphorbiaceae). *Journal of the Brazilian Chemical Society*, *18*(1), 11-33.

Saleem, M., Hussain, D., Anwar, H., Saleem, M., Ghouse, G., & Abbas, M. (2014). Predation Efficacy of *Menochilus sexmaculatus* Fabricus (Coleoptera: Coccinellidae) against *Macrosiphum rosae* under laboratory conditions. *Journal of Entomology and Zoology Studies*, *2*(3), 160-163.

Sánchez-Bayo, F., & Goka, K. (2014). Pesticide residues and bees–a risk assessment. *PLoS One*, *9*(4), e94482.

Wu, C., Zhang, H., He, M., Dong, F., Xu, J., Wu, X., & Liu, X. (2021). Toxicity of neonicotinoid insecticides on key non-target natural predator the larvae of *Coccinella septempunctata*. Environmental. *Environmental Technology & Innovation*, *23*, 101523.

Xiao, D., Zhao, J., Guo, X., Chen, H., Qu, M., Zhai, W., & Wang, S. (2016). Sublethal effects of imidacloprid on the predatory seven-spot ladybird beetle *Coccinella septempunctata*. *Ecotoxicology*, *25*, 1782-1793.

Yao, F. L., Zheng, Y., Zhao, J. W., Desneux, N., He, Y. X., & Weng, Q. Y. (2015). Lethal and sublethal effects of thiamethoxam on the whitefly predator *Serangium japonicum* (Coleoptera: Coccinellidae) through different exposure routes. *Chemosphere*, *128*, 49-55.

Yasmin, N., KHAN, M. F., Channa, M. S., & Ali, Z. (2008). Effects of a neem sample on protein patterns of *Bactrocera cucurbitae*. *Turkish Journal of Zoology, 32*(4), 415-419.

Yu, C., Fu, M., Lin, R., Zhang, Y., Yongquan, L., Jiang, H., and Brock, T.C. (2022). Toxic effects of hexaflumuron on the development of *Coccinella septempunctata*. *Environment Science and Pollution Research*, *21*, 1418-1424.

Yu, C., Lin, R., Fu, M., Zhou, Y., Zong, F., Jiang, H., & Brock, T. C. (2014). Impact of imidacloprid on life-cycle development of *Coccinella septempunctata* in laboratory microcosms. *Ecotoxicology and Environmental Safety*, *110*, 168-173.

Zada, R., Munir, I., & Khan, H. J. A. (2012). Population trend of canola aphid, *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae) and its associated natural enemies in different Brassica lines along with the effect of gamma radiation on their population. *Pakistan Journal of Zoology*, *44*(4), 225-239.

Zanuncio, J. C., Mourão, S. A., Martínez, L. C., Wilcken, C. F., Ramalho, F. S., Plata-Rueda, A., & Serrão, J. E. (2016). Toxic effects of the neem oil (*Azadirachta indica*) formulation on the stink bug predator,

©PagePal. All Rights Reserved.

Podisus nigrispinus (Heteroptera: Pentatomidae). *Scientific Reports*, *6*(1), 30261.

Zhao, Y., Wang, Z., & Yang, J. (2023). Persistence and efficacy of propiconazole and thiamethoxam in pest control: An analysis of non-target impacts. *Journal of. Agriculture and Food Chemistry*, 71(5), 1501-1510.

Shen, W., Fu, Y., Wang, L., Yao, Y., Zhang, Y., Li, M., Liu, H., Su, X. and Zhao, J. (2023). Transcriptomic analysis revealed that Low-Density aphid infestation temporarily changes photosynthesis and disease resistance but persistently promotes insect resistance in poplar Leaves. *Forests*, *14*(9), 1866.

Tembo, Y., Mkindi, A. G., Mkenda, P. A., Mpumi, N., Mwanauta, R., Stevenson, P. C., Ndakidemi, P. A., and Belmain, S. R. (2018). Pesticidal plant extracts improve yield and reduce insect pests on legume crops without harming beneficial arthropods. *Frontiers in Plant Science*, *9*, 1425-1432.

Upadhaya, S. G., Chapara, V., Rahman, M., & DelRío Mendoza, L.E. (2019). Efficacy of fungicide seed treatments in controlling Blackleg of Canola. *Plant Health Progress*, *20*(3), 160–164.

Wen, Q., Chen, R., Xu, T. and Hao, D. (2024). Functional characterization of terpene synthases from Masson Pine (*Pinus massoniana*) under feeding of *Monochamus alternatus* adults. *Forests*, *15*(2), 244.

Zeb, Q., Naeem, M., Khan, S.A., & Ahmad, S. (2016). Effect of insecticides on the population of aphids, natural enemies and yield components of wheat. *Pakistan Journal of Zoology*, *48*(6), 1839-1848.

Zhang, W., Kato, E., Bianchi, F., Bhandary, P., Gort, G., & Van Der Werf, W. (2018). Farmers' perceptions of crop pest severity in Nigeria are associated with landscape, agronomic and Socio-economic factors. *Agriculture Ecosystems & Environment*, *259*, 159-167.

Wen, Q., Chen, R., Xu, T., & Hao, D. (2024). Functional characterization of Terpene synthases from Masson Pine (*Pinus massoniana*) under feeding of *Monochamus alternatus* adults. *Forests*, *15*(2), 244.

Zeb, Q., Naeem, M., Khan, S.A., & Ahmad, S. (2016). Effect of insecticides on the population of aphids, natural enemies and yield components of wheat. *Pakistan Journal of Zoology*, *48*(6), 1839-1848.

Zhang, W., Kato, E., Bianchi, F., Bhandary, P., Gort, G., & Van Der, Werf, W. (2018). Farmers' perceptions of crop pest severity in Nigeria are associated with landscape, agronomic and Socio-economic factors. *Agriculture Ecosystems & Environment*, *259*, 159-167.

©PagePal. All Rights Reserved.

Disclaimer/Publisher's Note: The views, opinions, and data presented in all publications are exclusively those of the respective author(s) and contributor(s) and do not reflect the stance of Pagepal or its editorial team. Pagepal and the editor(s) disclaim any responsibility for harm to individuals or damage to property resulting from the use of any ideas, techniques, instructions, or products mentioned in the content.

©PagePal. All Rights Reserved.