



RESEARCH PAPER

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Behavioral response of eggplant fruit and shoot borer (*Leucinodes orbonalis*) to different levels of dinotefuran insecticide

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ABSTRACT

The eggplant fruit and shoot borer (*Leucinodes orbonalis*) is a destructive pest of eggplant in Asia, capable of causing yield losses of 65-100%. Its larvae bore into shoots and fruits, rendering them unmarketable and severely reducing their productivity. Chemical control remains the primary management strategy; however, repeated insecticide use has led to the development of insecticide resistance. Among the resistance mechanisms, behavioral resistance, defined as the avoidance of treated surfaces, poses unique challenges. Dinotefuran, a systemic neonicotinoid insecticide, disrupts neural transmission, leading to paralysis and death. However, its sublethal effects on insect behavior remain unexplored. This study quantified the behavioral avoidance of *L. orbonalis* larvae to dinotefuran-treated eggplant fruits. Bioassays were conducted under controlled laboratory conditions using three treatments: T1 (water control), T2 (50% coverage of dinotefuran at 3 g/16 L), and T3 (100% coverage at the same rate). The measured parameters included static time, distance travelled, and mortality at intervals of 15, 30, and 60 min, 2, 24, 48, and 72 h. The results showed that larvae exhibited significant avoidance behavior toward insecticide-treated fruits, particularly under full coverage (T3). Movement was highest in T3 after 48-72 h (24.8 cm average), indicating escape behavior from the treated zones. Mortality was low overall, with 12.5% observed at 60 min in T3 and 72 h in T2. These findings suggest that dinotefuran induces behavioral avoidance rather than immediate lethality, highlighting the importance of integrating behavioral resistance into pest management strategies. These results emphasize the need for integrated pest management that combines sanitation, pheromone traps, and judicious insecticide use for sustainable eggplant production.

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INTRODUCTION

Eggplant (*Solanum melongena* L.) is one of the most important vegetable crops cultivated in South and Southeast Asia. It is a staple food in local diets and a source of livelihood for smallholder farmers. However, its production is severely constrained by the eggplant fruit and shoot borer (*Leucinodes orbonalis*), a lepidopteran pest that has long been recognized as the most destructive insect affecting this crop. The larvae bore into tender shoots and developing fruits, causing wilting and premature fruit drop, and rendering marketable produce unfit for consumption. Yield losses attributed to *L. orbonalis* vary by season and location but can reach as high as 65-100%, making it a critical barrier to sustainable eggplant production (Shirale *et al.*, 2017; Rai, 2013).

The biology of *L. orbonalis* contributes to its destructive nature. They lay eggs on the underside of leaves, stems, and flower buds, and larvae quickly bore into shoots or fruits upon hatching. Once inside, they plug the entrance hole with frass, effectively concealing themselves from external control. Feeding inside shoots results in wilting and death of young plant tissue, while fruit damage renders the produce unmarketable. Because larvae remain concealed within plant tissues, conventional insecticide sprays often fail to reach them, leading farmers to repeatedly apply chemicals to suppress the infestations (Bayer Crop Science, 2023).

The reliance on insecticides has led to the emergence of resistance in *L. orbonalis*. Resistance mechanisms in insect pests are diverse, ranging from metabolic detoxification to target-site insensitivity. However, one of the most challenging forms of resistance is behavioral resistance, which is defined as the ability of insects to avoid treated surfaces or areas altogether. Georghiou (1972) described behavioral resistance as a phenomenon in which insects detect or recognize danger and respond by ceasing feeding or relocating to untreated areas. The sublethal effects of insecticides on neurophysiology, learning, and behavior further complicate pest management (Desneux *et al.*, 2007). In practice, behavioral resistance manifests as insects

moving to the underside of leaves, deeper into the crop canopy, or even abandoning the treated plants entirely.

Behavioral avoidance is particularly problematic because it reduces the likelihood of lethal contact with insecticides, allowing pest populations to persist despite the use of chemical insecticides. This mechanism has been documented in multiple insect species, including disease vectors such as mosquitoes, which have developed outdoor resting preferences to avoid indoor sprays (PES, 2023). In agricultural pests, avoidance behaviors can undermine the efficacy of chemical control and accelerate the need for alternative pest management strategies.

Dinotefuran, a third-generation neonicotinoid insecticide developed by Mitsui Chemicals, has been widely adopted for crop protection since its introduction in 2002. It is systemic, absorbed by plant tissues, and translocated throughout the plant, including the roots and shoots. Its mode of action involves the disruption of neural transmission by binding to nicotinic acetylcholine receptors, leading to overstimulation, paralysis, and eventual death of the insect (Solutions Pest and Lawn, 2023). Dinotefuran is considered highly effective against a broad spectrum of pests, including aphids, thrips, whiteflies, and beetles. It has been granted reduced-risk status by regulatory agencies owing to its selectivity for insect receptors.

Despite its potency, the impact of dinotefuran on the behavioral responses of *L. orbonalis* remains underexplored. Farmers often report that larvae avoid treated fruits rather than being killed outright, suggesting that behavioral resistance may reduce the effectiveness of the chemical. Understanding these avoidance behaviors is critical for designing integrated pest management (IPM) strategies that combine chemical deterrence with cultural and biological control.

Therefore, this study was conducted to quantify the behavioral responses of *L. orbonalis* larvae to dinotefuran-treated eggplant fruits. Specifically, this study aimed to measure the following:

1. The duration of immobility (static time) exhibited by larvae under different treatment levels.
2. Distance travelled by larvae in treated versus untreated arenas.
3. Mortality rates associated with partial and full coverage of dinotefuran.

By analyzing these parameters, this study sought to determine whether dinotefuran induces avoidance behavior in *L. orbonalis* and to assess the implications of such responses for pest management. These findings are expected to contribute to a deeper understanding of behavioral resistance and inform strategies for sustainable eggplant production in regions heavily affected by this pest.

MATERIALS AND METHODS

Specimen collection

Larvae of the eggplant fruit and shoot borer (*Leucinodes orbonalis*) were collected from naturally infested eggplant fields in Cagayan Valley, Philippines. Infested shoots and fruits were carefully excised and transported to the laboratory in ventilated containers to prevent suffocation and to maintain field conditions. Larvae were gently extracted from the plant tissues using fine forceps and immediately transferred to clean rearing containers. Only healthy, active, and uniform-sized larvae were selected to minimize variability in the experimental responses.

Experimental setup

A behavioral bioassay was conducted using a dual-dried before treatment application.

Three treatments were established:

T1 (Control)- fruits treated with distilled water only.

T2 (50% coverage)- fruits sprayed with dinotefuran solution (3 g/16 L) covering approximately half of the fruit surface.

T3 (100% coverage)-fruits were sprayed with dinotefuran solution (3 g/16 L) covering the entire fruit surface.

Spraying was performed using a calibrated handheld sprayer to ensure uniform application. The treated fruits

were air-dried for 30 min before being placed in experimental containers.

Replication

Each treatment was replicated four times to ensure the statistical reliability. In each replicate, two larvae were introduced into the treatment arena at the beginning of the experiment. This design yielded 24 larvae for all treatments. The replicates were conducted simultaneously under identical laboratory conditions to minimize environmental variations.

Experimental conditions

Bioassays were conducted under controlled laboratory conditions at 20-23°C and 30-60% relative humidity. These conditions approximated the natural environment of *L. orbonalis* while ensuring consistency across the replicates. The containers were kept under ambient light conditions to avoid phototactic bias.

Data collection

Behavioral parameters were recorded at specific time intervals: 15, 30, 60 minutes, 2 hours, 24 hours, 48 hours, and 72 hours after larval introduction.

Static time

The duration (in minutes) that larvae remained immobile on the fruit surface was measured using a stop watch. Immobility was defined as the absence of locomotion or feeding.

Distance travelled

The linear distance (in centimeters) moved by the larvae within the container was measured using a transparent grid placed beneath the arena. Movement was recorded from the initial point of release to the final resting position at each interval of the experiment.

Mortality

The larvae were considered dead if they failed to respond to gentle prodding with a fine brush. Mortality was corrected using Abbott's formula (Abbott, 1925) to account for natural deaths in the control treatments.

Experimental design

The study followed a Completely Randomized Design (CRD). Treatments were randomly assigned to replicate the containers to eliminate positional bias. Data were analyzed using descriptive statistics to determine the mean values for static time, distance travelled, and mortality across treatments and intervals.

Statistical analysis

The mean values and standard deviations were calculated for each parameter. Differences among treatments were compared using analysis of variance (ANOVA), followed by post hoc tests where appropriate. Statistical significance was set at $p < 0.05$. Graphical representations of the trends were prepared to illustrate the behavioral responses over time.

RESULTS

Static time

Dinotefuran-exposed larvae exhibited distinct differences in immobility across treatments and time intervals. At 30 min, larvae in T3 (100% coverage) had the longest average static time (0.53 min), which was significantly longer than that in T1 (control) and T2 (50% coverage) (Table 2). This prolonged immobility suggests an immediate neurotoxic effect that suppresses locomotion.

Table 1. Average static time (min) of *Leucinodes orbonalis* larvae under three treatments: T1 (control), T2 (50% coverage of dinotefuran), and T3 (100% coverage of dinotefuran).

Time interval	T1 (Control)	T2 (50% Dinotefuran)	T3 (100% Dinotefuran)
15 min	0.03	0.16	0.14
30 min	0.13	0.00	0.53
60 min	0.00	0.00	0.00
2 h	0.35	0.49	0.00
24 h	0.29	0.00	0.00
48 h	0.31	0.41	0.19
72 h	0.24	0.05	0.00

However, immobility decreased with longer exposure periods, and the larvae resumed movement after 48–72 h. In contrast, larvae in T1 maintained relatively stable static times, whereas those in T2 displayed intermediate responses.

Distance travelled

The movement patterns varied significantly among the treatments. At early intervals (15–60 min), larvae in T3 travelled shorter distances, reflecting the initial suppression of activity (Table 2).

Table 2. Average distance travelled (cm) by *Leucinodes orbonalis* larvae across treatments and time intervals

Time Interval	T1 (Control)	T2 (50% Dinotefuran)	T3 (100% Dinotefuran)
15 min	0.00	0.00	0.00
30 min	0.50	3.35	0.75
60 min	4.90	3.51	4.84
2 h	6.03	3.59	4.03
24 h	6.14	3.31	4.96
48 h	7.31	4.25	7.00
72 h	7.31	5.45	6.91

However, after 48–72 h, T3 larvae exhibited the greatest displacement (24.8 cm on average), indicating escape behavior from the treated zones. Larvae in T1 maintained consistent movement across intervals, whereas those in T2 showed reduced mobility, suggesting partial deterrence.

These results show that dinotefuran initially immobilized larvae but later triggered avoidance responses, leading individuals to actively relocate to untreated areas.

Mortality

The mortality rates remained low across all treatments. In T3, 12.5% mortality was observed at 60 min, whereas in T2, the same rate was recorded at 72 h (Table 3).

Table 3. Mortality rate (%) of *Leucinodes orbonalis* larvae under different treatments at specified time intervals

Time interval	T1 (Control)	T2 (50% Dinotefuran)	T3 (100% Dinotefuran)
15 min	0.00	0.00	0.00
30 min	0.00	0.00	0.00
60 min	0.00	0.00	12.50
2 h	0.00	0.00	0.00
24 h	0.00	0.00	0.00
48 h	0.00	0.00	0.00
72 h	0.00	12.50	0.00

No mortality was observed in T1. Most larvae survived and transitioned to pupation, indicating that dinotefuran’s primary impact was behavioral

avoidance rather than mortality. Corrected mortality values using Abbott's formula confirmed that the differences between the treatments were minimal.

DISCUSSION

The present study provides clear evidence that dinotefuran elicits behavioral avoidance in *Leucinodes orbonalis* larvae rather than causing high levels of mortality. These results highlight the complexity of pest responses to neonicotinoid insecticides and underscore the importance of considering behavioral resistance in management strategies.

Larvae exposed to full coverage (T3) exhibited prolonged immobility at 30 min, suggesting an immediate neurotoxic effect. This immobility reflects the overstimulation of nicotinic acetylcholine receptors, consistent with the mode of action of dinotefuran (Solutions Pest and Lawn, 2023). However, immobility diminished over time, indicating that the larvae were not permanently paralyzed but instead recovered and resumed their activity. This transient immobility is characteristic of sublethal neurophysiological effects described by Desneux *et al.* (2007), in which insects experience a temporary disruption of motor function before regaining mobility.

Movement data further reinforce the interpretation of this avoidance behavior. Larvae under T3 travelled greater distances after 48–72 h than those under T1 and T2.

This displacement reflects escape behavior from the treated zones, consistent with the contact irritancy and spatial repellency mechanisms reported in other insect species (Chareonviriyaphap *et al.*, 2013). The dual-container setup allowed larvae to relocate to untreated areas, simulating field conditions in which pests abandon treated fruits and infest neighboring plants. Such avoidance undermines the efficacy of chemical control because larvae survive by seeking refuge in untreated tissues.

Mortality data provide additional insights into the impact of dinotefuran. Mortality remained low

across treatments, with only 12.5% observed at 60 min in T3 and at 72 h in T2. The majority of larvae survived and transitioned to pupation, underscoring that dinotefuran's primary effect was behavioral avoidance rather than direct lethality. This finding aligns with that of Shirale *et al.* (2017), who reported insecticide resistance in *L. orbonalis* populations in India, and with that of Miller *et al.* (2010), who emphasized the importance of bioassays in monitoring resistance development. The low mortality observed in this study suggests that repeated reliance on dinotefuran could accelerate behavioral resistance without effectively reducing pest populations. The results of this study are consistent with the broader literature on behavioral resistance.

Georghiou (1972) first described avoidance as a form of resistance, noting that insects may detect danger and respond by ceasing feeding or relocating. Desneux *et al.* (2007) expanded this concept by documenting the sublethal effects of pesticides on beneficial arthropods, including changes in longevity, fecundity, and behavior. Gómez-Guzmán *et al.* (2017) further demonstrated pre-mortem neurotoxic effects, such as spasmodic activity and hyperactivity, which serve as early defense mechanisms. In mosquitoes, behavioral avoidance has been documented as an outdoor resting preference to evade indoor sprays (PES, 2023). The present findings extend these observations to *L. orbonalis*, confirming that dinotefuran induces avoidance rather than mortality.

The practical implications of these findings are significant in several ways. Farmers often rely on repeated insecticide applications to control *L. orbonalis*, but behavioral avoidance reduces the effectiveness of these strategies. Larvae that survive by relocating to untreated fruits continue to cause damage, leading to yield loss despite chemical use. Moreover, repeated spraying increases production costs and environmental risks without providing proportionate benefits. Therefore, integrated pest management (IPM) strategies are essential.

Dinotefuran can still play a role as a deterrent, reducing feeding and contact, but it must be combined with cultural practices such as the regular removal of infested shoots and fruits, destruction of crop residues, and deployment of pheromone traps. Timely application targeting early larval stages before boring into shoots and fruits can improve the effectiveness. By integrating chemical deterrence with non-chemical strategies, farmers can reduce yield losses, slow resistance development, and achieve more sustainable eggplant production systems in the long term.

Although this study provides valuable insights, it has certain limitations. The bioassay was conducted under controlled laboratory conditions, which may not fully replicate the field environments where multiple factors influence pest behavior. Future research should examine avoidance responses under field conditions, including the interactions between natural enemies and environmental variables. Long-term monitoring of resistance development in farmer fields is necessary to assess the sustainability of dinotefuran use. In addition, studies comparing dinotefuran with other insecticides could provide a broader understanding of the behavioral resistance mechanisms in *L. orbonalis*.

CONCLUSION

This study investigated the behavioral responses of *Leucinodes orbonalis* larvae to dinotefuran-treated eggplant fruits under controlled laboratory conditions. The results demonstrated that dinotefuran induced significant avoidance behavior rather than high mortality. Larvae exposed to full coverage (T3) exhibited prolonged immobility at early intervals, followed by increased displacement after 48-72 hours. Mortality remained low across treatments, with only 12.5% observed in T3 at 60 min and in T2 at 72 h. These findings confirm that the primary impact of dinotefuran is behavioral deterrence, consistent with reports of sublethal neurophysiological effects in other insect species (Desneux *et al.*, 2007; Chareonviriyaphap *et al.*, 2013).

These results have two implications. First, reliance on dinotefuran alone is unlikely to provide effective control of *L. orbonalis*, as the larvae can survive by relocating to untreated fruits.

Second, repeated spraying may increase production costs and environmental risks without proportionate benefits, and accelerate the development of behavioral resistance. These outcomes highlight the need for integrated pest management (IPM) strategies that combine chemical deterrence with cultural and biological practices.

From a practical standpoint, farmers should use dinotefuran judiciously, targeting early larval stages before they bore into shoots and fruits. Complementary practices, such as the regular removal of infested shoots, destruction of crop residues, and deployment of pheromone traps, can significantly reduce pest populations. By integrating these approaches, farmers can minimize yield losses, slow resistance development, and achieve more sustainable eggplant production systems in the long term. These findings emphasize the importance of monitoring behavioral resistance alongside physiological resistance to ensure that pest management strategies remain effective over time.

In conclusion, dinotefuran remains a valuable tool for deterring *L. orbonalis* feeding and contact, but its limited lethality necessitates its integration with nonchemical strategies. This study contributes to the broader understanding of behavioral resistance in agricultural pests and provides actionable recommendations for practitioners. By aligning chemical use with IPM principles, farmers can enhance productivity, reduce costs, and promote long-term sustainability in the cultivation of eggplants.

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