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Research Paper

Efficacy of three different insecticides on maize stem borer (*Chilo partellus*) under controlled conditions

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Abstract

Maize is the third most important crop after rice and wheat in Pakistan. It is used extensively for food production as well as in sectors like animal feed and biofuels. Several factors are responsible for decreasing maize yield but one of the main factors are insect pest especially Maize Stem Borer *Chilo partellus* (Pyralidae; Lepidoptera) a serious sorghum and maize pest that reduces yields by 26.7% to 80.4%, poses a serious threat to its production. While the pest bores into the stem of adult plants, decreasing productivity, it destroys the shoot of new plants, resulting in a "dead heart." We tested the effectiveness of three commercially available insecticides to assess control methods: pyrifluquinazon (20% WG, Jaffer Agro Services Pvt. Ltd., Pakistan); lufenuron (Match 50 EC, Syngenta, Pakistan); and dinotefuran (20% SG, Kanzo Ag Pvt. Ltd., Pakistan). Larvae were exposed to treated leaves in petri dishes using a leaf-dip bioassay, and mortality was noted every 24 hours for three days. Pyrifluquinazon was the least effective of the three, exhibiting only 24% mortality at the maximum concentration (62.5 µg/ml) after 72 hours. With a death rate of 36% after 72 hours, dinotefuran was the most effective, followed by lufenuron at 28%. The effectiveness of lufenuron drastically decreased at lower dosages. These findings suggest that, out of all the pesticides tested, dinotefuran is the most effective.

1. Introduction

Around 200 million hectares (mha) are used to grow the three main staple grains in the world: rice, maize, and wheat. More than 9,000 years ago, maize (*Zea mays* L.), was domesticated in southern Mexico and America (Kennett et al., 2020). It is a multifunctional crop and major cereal, maize (*Zea mays* L.) offers several uses, including human food, animal, poultry feed, and animal fodder (Gul et al., 2021). It offers the calories required for daily metabolism and is a good source of

minerals, vitamins A, B, and E. Additionally, maize oil is the most extensively used vegetable oil worldwide due to its relatively lower cost compared to other (Orhun et al., 2013).

The nutritional content of maize grain includes 72% carbohydrates, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar, and 1% ash (Shah et al., 2015; Ullah et al., 2010). In 2023, the top five cereals produced were maize, rice, wheat, barley, and sorghum. Among the major cereals, maize had the largest production (1.2 billion tonnes) and the quickest growth (46 percent) since 2010. This is because maize is utilized extensively in industries other than food, such as animal feed and biofuels. Maize output returned from the 2022 decrease, which was linked to extensive droughts in Europe, and exceeded the 2021 level in 2023 (FAO, 2024). After rice and wheat, maize is Pakistan's third main cereal crop, accounting for 0.7% of the country's GDP. A total of 1.65 million hectares of maize were grown in 2021–2022, representing a 16.6% increase over the 1.40 million hectares planted the previous year (MNSFR, 2023). In two districts (Kasur and Lahore), a two-year (2018–2019) survey of the species biodiversity of insect pests in field maize crops was conducted. In this study, 49 pest species from 45 genera, 27 families, and 6 orders were identified. With 49.17% of all pests caught, Noctuidae dominated the other insect groups (Akhtar et al., 2024). Millions of smallholder farmers' livelihoods and food security have been negatively impacted by fall armyworm, when it first appeared in Africa in 2016 and Asia in 2018 in maize (Prasanna et al., 2022). Besides the loss of FAW, some other lepidopterans damage the maize plant and cause yield loss, with stem borers being significant. It can cause damage ranging from 26.7% to 80.4% (Chouraddi & Mallapur, n.d.). In immature plants, it kills the shoot, resulting in a "dead heart," while in older plants, it causes boring activity that damages the upper stem (Salman et al., 2024a). An effective method for managing fall armyworm and other lepidopteran pests of maize that has been genetically modified to produce insecticidal proteins from the bacterium *Bacillus thuringiensis (Bt)* (Van Den Berg et al., 2021).

Lepidopteran stem borers, *Busseola fusca* (native) and *Chilo partellus* (invasive), pose serious challenges to cereal crops in Africa, particularly maize, resulting in large yield losses. *B. fusca* is primarily found at high elevations, while *C. partellus* is found in lowlands and spreads widely (Khadioli et al., 2014; Sylvain et al 2015). Using temperature-dependent growth models and climate projections, the study assessed at how global warming would increase the range of *C. partellus.* While extreme temperatures (15°C, 38°C) hindered survival, rising temperatures (18–35°C) shortened the time needed for development. Since 80% of the region's maize is grown in high-altitude regions of East Africa, and other areas of Asia (Khadioli et al., 2014). In 2016, incidence of *Chilo partellus* were assessed in seven of Punjab's principal districts that grow maize. Okara district had the lowest total incidence of maize borer (1%) while Khanewal district had the highest (12%), followed by Multan (6%) and Khanewal district. Conversely, district Vehari had the highest prevalence of maize borer (100%) followed by Khanewal and Multan (73%) and district Sahiwal had the lowest frequency (33%) (Nabeel et al., 2018).

Maize in Pakistan's third-largest grain crop (Nabeel et al., 2018), can lose up to 30% of its production. According to a survey of 812 farmers, more pest damage lowers production, which in turn lowers incomes and exacerbates poverty (Ali & Beshir, n.d.). During two seasons, the study examined maize yields in plots with and without *Chilo partellus* infestation. The infestation decreased yields by 2,860 kg/ha (33% affected plants) in the autumn and 2,121 kg/ha (25.2% affected plants) in the spring. Instead of larval tunnelling, the main damage was caused by dead hearts and stunted growth (Mohyuddin & Attique, 1978).

In Malawi, Africa, *C. partellus* was initially discovered in 1932 (Tams, 1932). Since than it has spread to other areas of Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe (Overholt et al., 2000; Sylvain et al.,

2015). Due to losses caused by this pest, we have to make an effort to control this pest. We use three pesticides first one was pyrifluquinazon, the second one was dinotefuran, and the third one was lufenuron. Due to the resistance of insects to insecticides, we use new kinds of insecticides like pyrifluquinazon. Pyriquinazon, an insecticide that is a member of the quinazoline class, is a distinct chemical. It has strong control against sucking pests, especially against whitefly. A third-generation neonicotinoid (IRAC Group 4A), dinotefuran, functions in the nervous system of insects as an agonist of the nicotinic acetylcholine receptor (nAChR). It is used against many insects like Aphids, Whiteflies and Jassids (Salama et al., 2022), thrips, leafhoppers (Gosh et al., 2014), and some soil-dwelling pests (Bhuvaneswari et al., 2022)**.** It is used against mosquito control.(Corbel et al., 2004). The third one, lufenuron, is used against chewing pests; it is a chitin synthesis inhibitor (Islam et al., n.d.; Muhammad Salman et al., 2024b).

2. Materials and Methods

We collected enough maize stem borer larvae from Muhammad Nawaz Sharif University of Agriculture's C block in Multan. To preserve the larvae's vitality during the journey, they were carefully moved to the lab in ventilated containers lined with wet filter paper. From the gathered population, healthy third-instar larvae with consistent size and vigor were chosen for the experiment. The toxicological effects of three commercially available insecticides were assessed: dinotefuran (20% SG from Kanzo Ag Pvt. Ltd., Pakistan), lufenuron (Match 50 EC from Syngenta, Pakistan), and pyrifluquinazon (20% WG from Jaffer Argo Service Pvt. Ltd., Pakistan). Five serial dilutions of each insecticide (62.5, 31.25, 15.62, 7.81, and 3.9 ppm) were made in 500 ml glass beakers with 100 mL of distilled water acting as the solvent.

Throughout the experiment, all beakers were carefully labelled with numbers (1–5 for test concentrations in descending order of strength, and 6 for the control) to avoid confusion. According to established procedures, the leaf-dip bioassay method was used. Using distilled water, fresh maize leaves of comparable size were thoroughly cleaned and wiped dry. After that, for 30 minutes, these leaves were fully submerged in their corresponding treatment solutions to provide even coverage. The leaves were air-dried on sterile filter paper for about 45 minutes after treatment, under laboratory conditions (kept at 26±2°C temperature and 70-75% relative humidity) until no moisture was apparent.

Five duplicate Petri dishes were made for each concentration, with one set up per Petri dish to give a sufficient feeding area and 25 treated leaves. A gentle camel-hair brush was used to gently transfer third-instar larvae into each Petri dish in order to avoid harm. With a light: dark photoperiod of 12:12 hours, the experimental setup was kept in a controlled setting to mimic natural conditions. Mortality evaluations were carried out 24, 48, and 72 hours after the application of the therapy. When larvae remained motionless after being gently shaken with a camel hair brush, they were deemed dead. Initial observations were made 24 hours after treatment to evaluate immediate toxicity effects, and then readings were taken 48 and 72 hours later to assess delayed and cumulative mortality. Data collection was done methodically. Standardized datasheets were used to record all of the data, which were then converted to digital format for analysis.

Using "Probit" software, the experiment's results were analyzed and the average mortality in each experimental unit was determined. The percentage mortality was calculated in MS Excel 2019.

3. Results

Pyrifluquinazon (Matoi) Performance: Pyrifluquinazon demonstrated the lowest efficacy among the three tested insecticides. At the highest concentration (62.5 µg/ml), mortality rates reached only 9% after 24 hours, gradually increasing to 15% at 48 hours and 24% by 72 hours (Table 1/Figure 1). The dose-response relationship was particularly weak at lower concentrations, with 3.90 µg/ml producing merely 2-9% mortality over the same period. Analysis revealed exceptionally high LC_{50} values, starting at 865.854 µg/ml (24h) and decreasing to 24.250 µg/ml by 72 hours (Table 1), indicating poor initial activity and only moderate improvement with prolonged exposure. The shallow slope (0.829±0.220 at 72h) (Table 1) further confirmed inconsistent dose-dependent mortality. These results suggest Pyrifluquinazon may require substantially higher field application rates or formulation improvements for effective maize stem borer control.

Table 1. LC_{50} of three different Insecticides against the maize stem borer.

Chemicals	Hours	Total numbers	LC_{50} and 95% confidence limit (µg/ml)	Slope ±SE	Chi-square	Order of toxicity	df	rr
Pyrifluquinazan	24	39	865.854(141.640-9.125E+10)	0.662±0.280	0.243	9	3	213.474
	48	39	151.974(53.229-41887.038)	0.638±0.234	0.487	8	3	37.468
	72	39	24.250(14.635-54.036)	0.829±0.220	0.325	5	3	5.978
Dinotefuran	24	39	22.708(13.394-50.708)	0.800±0.219	0.213	4	3	5.598
	48	39	10.202(2.431-20.566)	0.613±0.216	0.053	2	3	2.515
	72	39	4.056(1.426-6.674)	1.094±0.246	0.392	1	3	
Lufenuron	24	39	118.895(69.261-437.073)	1.613±0.378	0.746	7	3	29.313
	48	39	89.255(48.366-396.917)	1.045±0.254	0.090	6	3	22.005
	72	39	15.451(9.972-23.761)	1.064±0.225	1.588	3	3	3.809

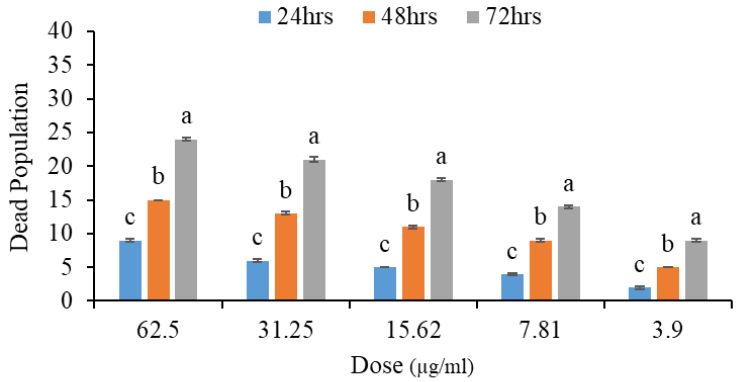


Figure 1. Mortality percentage in the 3rd larval instar of maize stem borer when treated with Pyrifluquinazan by the leaf dip method.

Different small letters above each bar indicate significant difference among times of mortality within a block of each dose using one-way ANOVA, LSD test, and at $P < 0.05$.

Dose1: $F_{2,12}$ =85.5, P<0.0001, Dose 2: $F_{2,12}$ =28.2, P<0.0001, Dose 3: $F_{2,12}$ =50.8, P<0.0001, Dose 4: $F_{2,12}$ =25, P<0.0002, Dose 5: $F_{2,12}$ =14.8, P<0.0007

3.1 Dinotefuran Superior Efficacy

Dinotefuran emerged as the most potent insecticide in the study. At 62.5 µg/ml, it achieved 24% mortality within 24 hours, increasing to 27% at 48 hours and reaching 36% by 72 hours (Table 1). Even at the lowest concentration (3.90 µg/mL), it maintained a 10-20% mortality rate across the observation period (Table 1). The LC_{50} values showed a remarkable temporal improvement, decreasing from 22.708 µg/ml (24 h) to 4.056 µg/ml (72 h), demonstrating both rapid knockdown and increasing residual activity (Table 1). The steep slope (1.094±0.246 at 72h) and excellent model fit (χ^2=0.392) indicated a strong, predictable dose-response relationship (Table 1, Figure 2). These characteristics position Dinotefuran as an ideal choice for situations requiring both immediate and sustained pest control.

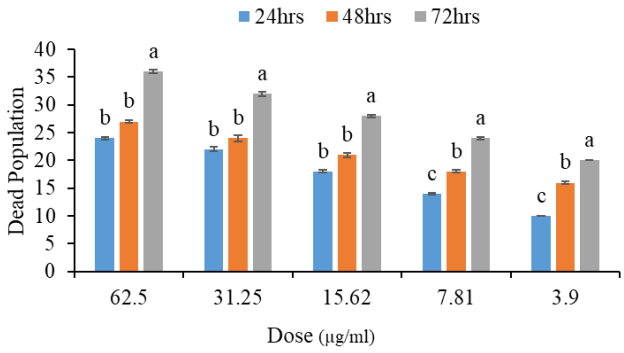


Figure 2. Mortality percentage in the 3rd larval instar of maize stem borer when treated with Dinotefuron by the leaf dip method.

Different small letters above each bar indicate significant difference among time of mortality within a block of each dose using one-way ANOVA, LSD test, and at $P < 0.05$.

Dose 1: $F_{2,12}$ =19.5, P<0.0003, Dose 2: $F_{2,12}$ =5.09, P<0.0252, Dose 3: $F_{2,12}$ =12.2, P<0.0014, Dose 4: $F_{2,12}$ =21.7, P<0.0002, Dose 5: $F_{2,12}$ =76, P<0.0001

3.2 Lufenuron Intermediate Performance

Lufenuron exhibited intermediate toxicity characteristics. While it achieved 28% mortality at 62.5 µg/ml by 72h, its performance dropped sharply at lower concentrations (0% mortality at 3.90 µg/ml after 24h) (Table 1). The LC_{50} values decreased from 118.895 µg/ml (24h) to 15.451 µg/ml (72h), showing slower action compared to Dinotefuran but better efficacy than Pyrifluqunazon. The slope values (1.064±0.225 at 72h) suggested moderately consistent dose-response patterns. Lufenuron's delayed but progressive mortality pattern makes it potentially suitable for preventive applications where immediate knockdown isn't required (Table 1; Figure 3).

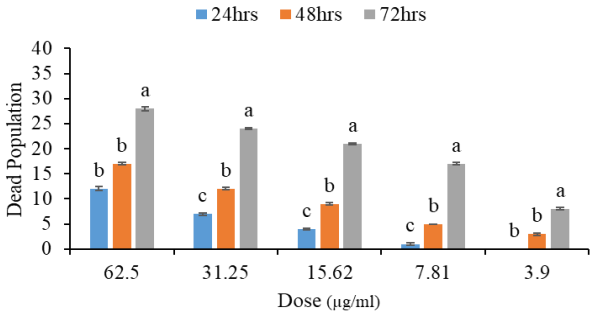


Figure 3. Mortality percentage in the 3rd larval instar of maize stem borer when treated with Leufenoron by the leaf dip method.

In Figure 3, different small letters above each bar indicate significant difference among times of mortality within a block of each dose using one-way ANOVA, LSD test, and at $P < 0.05$.

Dose 1: $F_{2,12} = 21.2$, $P<0.0002$, Dose 2: $F_{2,12} = 57.3$, $P<0.0001$, Dose 3: $F_{2,12} = 76.3$, $P<0.0001$, Dose 4: $F_{2,12} = 83.2$, $P<0.0001$, Dose 5: $F_{2,12} = 16.3$, $P<0.0005$

3.3 Comparative Analysis and Practical Implications

The study established a clear efficacy hierarchy: Dinotefuran > Lufenuron > Pyrifluquinazon. Dinotefuran's combination of rapid action (low 24h LC_{50}), increasing potency over time, and reliable dose-response makes it particularly valuable for resistant pest management. Lufenuron may serve as an alternative in rotation programs to prevent resistance development, while Pyrifluquinazon poor performance suggests limited standalone utility against maize stem borer. These findings should inform integrated pest management strategies, particularly in regions with high pest pressure, where Dinotefuran's superior efficacy could significantly reduce crop losses. Future research should investigate field performance under varying environmental conditions and potential synergies between these compounds.

4. Discussion

In our study, we use a leaf dip bioassay of three insecticides with different modes of action, and these three them (Pyrifluquinazon, dinotefuran & lufenuron) have shown different results. First, we discuss dinotefuran.

Dinotefuran is a neonicotinoid, act on the nervous system (nicotinic acetylcholine receptors), delivering fast knockdown and showing low LC_{50} values in a wide range of insect orders. In our results at 72-h LC_{50} 4.06 µg/ml for dinotefuran against maize stem borer. In studies with *Bemisia tabaci* from Florida, LC_{50} values ranged from 0.043 to 3.350 ppm (µg/ml) (Smith et al., 2016).Another laboratory bioassay on okra leafhopper using a 20 g/L dinotefuran formulation reported an LC_{50} of 7.60 ppm (µg/ml) (Rekha et al., 2017).A glasshouse bioassay reported a 24-h LC_{50} of 0.415 ppm (µg/ml) for Dinotefuran 20 SG against brown plant hopper (*Nilaparvata lugens*), showcasing strong toxicity under controlled condition. In laboratory dietary toxicity assays, *Aromia bungii* (red-necked longhorn beetle), a significant wood-boring pest, exhibited moderate susceptibility to Dinotefuran. The reported LC_{50} for neonate larvae over a 12-week period was approximately 2.2 µg/ml, with a 95% confidence interval of 0.78–6.51 µg/ml. At concentrations of ≥10 µg/ml, larval survival dropped sharply to below 13%, and feeding activity was significantly inhibited at as low as 1 µg/ml in neonates (Sunamura et al., 2021). These findings suggest Dinotefuran has potential for managing wood borers, but only at relatively higher concentrations than are needed for typical sap-feeding pests.

Even the highest field-derived value (3.35 µg/ml) is slightly below your 4.06 µg/ml, suggesting maize stem borer is similarly or slightly less susceptible than whitefly. Given Dinotefuran's known strong efficacy in managing sucking pests. Insect growth and development during molting are influenced by lufenuron, an inhibitor of chitin production, which can disrupt the chitin of the exoskeleton by touch because of its lipophilic characteristics. Moreover, increased concentrations have an anti-feeding impact (Gelbic et al., 2011). In our study at 72-h LC_{50} for Lufenuron is 15.45 µg/ml (CI: 9.97–23.76). This value, while moderate, contrasts sharply with its significantly lower LC_{50} in other lepidopterans. For example, *Spodoptera litura* (third instars) display LC_{50}s of just 0.76 µg/ml , and even leaf miner *Tuta absoluta* second instars show LC_{50} ≈ 14.65 µg/m—similar to your findings(Radwan & Taha, 2017). In laboratory assays on the lesser

grain borer (*Rhyzopertha dominica*), Lufenuron applied at 0.8 ppm completely inhibited F_1 adult emergence and significantly reduced egg hatchability, with ~80% adult mortality after 21 days (Mahmoud et al., 2022). The higher threshold for stem borer suggests a lower cuticular penetration or reduced molting disruption, typical IGR action that targets chitin synthesis.

Pyrifluquinazon is a relatively new insecticide belonging to the quinazoline class, and its mode of action (MoA) is unique compared to conventional insecticides. It which interferes with the coordination and feeding habits of insects by attacking their chordotonal organs. It is a derivative of pyridine azomethine (Spalthoff et al., 2023) is categorized by the (IRAC classification) as a Group 9B insecticide. The 72-h LC_{50} for Pyrifluquinazon in your study is 24.25 µg/ml (CI: 14.64–54.04). In contrast, baseline whitefly (*B. tabaci*) populations exhibit significantly higher susceptibility, with LC_{50}s of just 1.24 mg/L (≈ 1.24 µg/ml) (Wen et al., 2023). This difference confirms its pest-specific efficacy: while effective against whitefly via feeding inhibition, its performance against boring Lepidoptera is markedly poor. Chewing insects digest plant tissue directly and do not ingest phloem sap, so they're unlikely to encounter lethal doses. This is consistent with our observation that even at the highest dose (62.5 µg/ml), mortality remained below 24% after 72 hours.

Authors contributions

Muhammad Tayyab Abbas: Methodology, Software, Validation, Rashid Azad: Visualization, Writing – original draft, Shah Zaib Noor: Writing – review & editing. : Data curation, Muhammad Muazzam: Investigation. Muhammad Naeem: Investigation, Formal analysis. Muhammad Zeeshan Khalid: Conceptualization, Methodology, Project administration, Resources, Writing review & editing. Nabeel Shafiq: Conceptualization, Investigation, Methodology, Muhammad Faizan: Project administration, Resources, Waqar Jaleel: Supervision, Validation, Writing – original draft,

Conflict of interest

Authors have declared that no competing interests.

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