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Comparative Efficacy of Insecticides against Fall Armyworm (*Spodoptera frugiperda*) on Pertiwi Exotic Sweet Corn under Field Conditions

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ABSTRACT

Fall armyworm (*Spodoptera frugiperda*) is an important constraint on sweet corn production. This study compared eight insecticide active ingredients with an untreated control for suppressing the pest on the Pertiwi Exotic cultivar. The field experiment followed a randomized complete block design comprising nine treatments, three blocks, and 27 plots. The evaluated active ingredients were chlorantraniliprole, cyantraniliprole, emamectin benzoate, indoxacarb, methomyl, cypermethrin, chlorpyrifos, and fipronil. Insecticide treatment significantly influenced larval abundance, attack incidence, damage severity, and cob weight. Several treatments reduced the recorded larval population to zero at the final assessment and consequently produced 100% efficacy relative to the untreated control. Cypermethrin exhibited comparatively low performance under the conditions of the experiment; however, this field response alone cannot confirm resistance. The results show that insecticide choice materially affected pest suppression and yield protection.

Keywords: attack incidence, fall armyworm, insecticide efficacy, Spodoptera frugiperda, sweet corn

INTRODUCTION

Sweet corn (Zea mays L. saccharata) is a horticultural crop with substantial economic value and increasing demand in Indonesia. Consumer acceptance is closely related to kernel sweetness, cob shape, kernel uniformity, and freedom from physical injury. Field productivity and marketable quality may decline when crop management is inadequate, particularly when plants are exposed to pest attack (Astiningrum et al., 2020; Bersinar et al., 2021).

National corn production rose from 30.141 to 31.633 million tons, yet plant pests remain an important production constraint. Crop losses attributed to plant-disturbing organisms have been reported to reach 80% under severe conditions (Nurmaisah, 2021). Among the major pests, fall armyworm is especially damaging because it is polyphagous, highly invasive, and capable of

attacking corn from the vegetative stage through cob development. Larvae feed within the whorl and on young leaves, potentially injuring the growing point and reducing yield when control is delayed (Deden et al., 2023).

Chemical control remains widely used against fall armyworm, although insecticides differ in efficacy and non-target effects. Chlorantraniliprole has controlled lepidopteran larvae in shallot and can move upward through corn xylem following seed or foliar application (Febrianasari et al., 2014; Pes et al., 2020). Emamectin benzoate has also reduced Spodoptera damage in other crops (Supriyadi, 2021), while indoxacarb has shown activity against fall armyworm on corn (Rohmah et al., 2022). Evidence from previous studies further indicates that methomyl, cypermethrin, chlorpyrifos, and fipronil differ in acute toxicity and effects on non-target organisms (Rochman, 2017; Rustam et al., 2019; Wahyudin et al., 2024). These differences underscore the need to compare products under local field conditions.

Active ingredients vary in mode of action, speed of feeding cessation, persistence, and efficacy against the target pest. Their field performance may therefore differ even when they are applied to the same crop and pest population. This study compared the response of fall armyworm on Pertiwi Exotic sweet corn to eight insecticide active ingredients and examined how pest suppression was associated with crop damage and cob yield.

MATERIALS AND METHODS

Study Site and Period

The field trial was carried out from February to May 2026 in Katileng Hamlet, Luwung Village, Mundu District, Cirebon Regency. The site, situated approximately 4 m above sea level, was selected because fall armyworm occurs endemically in the area.

Materials and Equipment

The experiment used Pertiwi Exotic sweet corn seed, organic fertilizer, NPK Phonska (15–15–15), and several commercial insecticides. The evaluated active ingredients, trade names, formulations, and applied concentrations were: chlorantraniliprole (Prevathon 50 SC, 2 ml/L), cyantraniliprole (Preza 100 OD, 2 ml/L), emamectin benzoate (Emacel 30 EC, 1 ml/L), indoxacarb (Ammate 150 EC, 0.4 ml/L), methomyl (Lannate 25 WP, 1.8 g/L), cypermethrin (Sidamethrin 50 EC, 2 ml/L), chlorpyrifos (Neoban plus 540/60 EC, 3 ml/L), and fipronil (Regent 50 SC, 4 ml/L). Field equipment consisted of hoes, a 5-liter capacity manual sprayer, scales, a camera, rulers, measuring tapes, stationery, plot labels, and measuring cups. Insecticides were applied using a standard spray volume of 500 L/ha. Applications were scheduled at 14, 21, 28, 35, and 42 days after planting (DAP). Spraying was conducted uniformly in the morning between 06:00 and 07:00 AM. Weather conditions during the application dates fluctuated between clear skies and intermittent rainfall.

Experimental Design

The field experiment was arranged in a randomized complete block design (RCBD). Nine treatments were allocated within each of three blocks, giving a total of 27 plots. Blocks were established to account for potential gradients in soil fertility and field heterogeneity. Each experimental unit consisted of a 4 x 1 m plot containing a population of 20 sweet corn plants. The seeds were planted at a spacing of 40 x 30 cm. To prevent insecticide spray drift between treatments, a 50 cm buffer zone was maintained between all adjacent plots. Treatments were randomly assigned to the plots within each block using a manual lottery method.

Treatments were coded as follows:
A : Control (without insecticide application)
B : Active ingredient of insecticide Chlorantraniliprole
C : Active ingredient of insecticide Cyantraniliprole
D : Active ingredient of insecticide Emamectin Benzoate
E : Active ingredient of insecticide Indoxacarb
F : Active ingredient of insecticide Methomyl
G : Active ingredient of insecticide Cypermethrin
H : Active ingredient of insecticide Chlorpyrifos
I : Active ingredient of insecticide Fipronil

Larval populations were assessed at 20, 27, 34, 41, and 48 days after planting (DAP). The manuscript should additionally specify how many plants were sampled in each plot, how they were selected, and whether the same plants were assessed over time.

Measured Variables

Plants in every experimental plot were inspected visually for fall armyworm injury. The proportion of attacked plants, referred to here as attack incidence (IS), was calculated using the equation adapted from Agrios (2005):

$$\boldsymbol{IS = \frac{a}{a+b} \times 100\%}$$

Where:
IS: attack incidence (%)
a: Number of plants attacked
b: Number of plants that are not attacked

Leaf injury was rated on a five-level scale from 0 to 4. The score assigned to each plant reflected the visible extent of feeding injury:

0 = no feeding injury; leaves and whorl remained normal and the plant grew normally.
1 = minor injury affecting approximately 1–25% of the assessed tissue, including small edge bites or a few spots on one or two leaves and slight whorl scratching.
2 = moderate injury affecting approximately 25–50% of the assessed tissue, including distinct holes, eroded margins, mild curling, and moderate tearing of the whorl.
3 = severe injury affecting approximately 50–75% of the assessed tissue, with extensive feeding on several leaves, substantial whorl injury, and visible reduction in vegetative growth.
4 = very severe injury affecting more than 75% of the assessed tissue; leaves were largely consumed, the whorl was extensively exposed or destroyed, and plant or cob development was strongly impaired.

Damage intensity (IK) was estimated from the injury scores using the Townsend and Heuberger (1943) equation:

$$IK = \frac{\sum(n \times v)}{N \times Z} \times 100\%$$

Where:
IK Damage severity (%)
n: Number of plants or plant parts with a certain score value
v: Score value (attack category)
N: Total number of plants observed
Z: The highest score on a scale (0-4)

The relative efficacy of each insecticide treatment was calculated from post-treatment larval counts in the treated and untreated plots using Abbott's equation (Abbott, 1925):

$$EI = \frac{C - T}{C} \times 100\%$$

Where:
EI = effectiveness of the tested insecticide (%)
C = Population of *Spodoptera frugiperda* in the control plot after application
T = Population of *Spodoptera frugiperda* in the treated plot after application

Data Analysis

Prior to the analysis of variance (ANOVA), data were evaluated for the assumptions of normality and homogeneity of variances. To meet these statistical assumptions, count data corresponding to larval abundance were subjected to a square root transformation, $\sqrt{x + 0.5}$. Proportion and percentage data, including attack incidence, damage intensity, and insecticide efficacy, were transformed using the arcsine square root function, $\arcsin\left(\sqrt{x/100}\right)$.

Because variables were measured repeatedly from the same experimental units over time, data for each observation date (Days After Planting) were analyzed separately using an ANOVA based on a Randomized Complete Block Design (RCBD) model to account for block and treatment effects. When the treatment effect was statistically significant, mean separations were performed using the Scott–Knott clustering procedure at $\alpha = 0.05$. All statistical computations, including data transformations and variance analyses, were performed using Microsoft Excel. Although transformed data were used for the statistical tests to ensure valid *P*-values, the original untransformed means are presented in the results tables for clarity.

RESULTS AND DISCUSSION

Larval populations and plant damage were assessed at 20, 27, 34, 41, and 48 days after planting (DAP). A total census method was applied within each experimental unit, meaning all 20 plants in every plot were observed at each assessment date. Consequently, the exact same population of plants was evaluated consistently throughout the observation period, amounting to a total of 60 observed plants per treatment (20 plants × 3 blocks).

Table 1 shows a clear divergence between the untreated plots and plots receiving insecticide. Counts fluctuated during the vegetative period, but the contrast became more pronounced as the crop approached the generative stage.

Table 1. Fall armyworm larval abundance

Treatment	*Of Spodoptera frugiperda* pest				
	20 DAP	27 DAP	34 DAP	41 DAP	48 DAP
Control (A)	24	20	33	47	68
Chlorantraniliprole (B)	14	8	9	0	0
Cyantraniliprole (C)	10	11	0	0	0
Emamectin Benzoate (D)	12	5	1	0	0
Indoxacarb (E)	14	9	2	2	0
Methomyl (F)	8	9	0	0	0
Cypermethrin (G)	6	18	20	5	1
Chlorpyrifos (H)	11	10	0	0	0
Fipronil (I)	8	18	4	4	1

At 20 DAP, 24 larvae were recorded across plants in the untreated control. Corresponding counts in insecticide-treated plots ranged from 6 to 14. By 48 DAP, the control population had increased to 68 larvae. In the absence of treatment, adults could continue ovipositing while developing larvae had access to abundant corn foliage. In contrast, most insecticide treatments progressively suppressed larval abundance (Darmawan Septian et al., 2021). The sampling denominator should be confirmed because the original wording alternated between aggregated counts and counts per plant.

From 34 to 48 DAP, chlorantraniliprole (B), cyantraniliprole (C), emamectin benzoate (D), methomyl (F), and chlorpyrifos (H) reduced the recorded population to zero by the final observation. The diamides chlorantraniliprole and cyantraniliprole act on insect ryanodine receptors, disrupting calcium regulation and causing feeding cessation and paralysis (Pes et al., 2020). Methomyl and chlorpyrifos act on the insect nervous system through acetylcholinesterase inhibition, although their field use must follow registration and label requirements (Bakry & Gad, 2023).

Attack Intensity (%)

Attack incidence increased with crop age at 20, 27, 34, 41, and 48 DAP. Nevertheless, the magnitude of the increase differed among treatments, indicating that insecticide application influenced the proportion of injured plants (Table 2).

The untreated control had an attack incidence of 53.33% at 20 DAP, rising to 86.67% at 48 DAP. This pattern is consistent with the feeding behavior of fall armyworm larvae, which scrape leaf tissue, create irregular holes, and frequently remain protected within the corn whorl (Wilyus et al., 2022). Although injury was still observed in treated plots, its incidence was generally lower than in the control.

At 48 DAP, chlorpyrifos (H) produced the lowest reported attack incidence (55.00%), followed by chlorantraniliprole (B; 60.00%) and fipronil (I; 66.67%). Visible feeding marks may remain even when an insecticide acts rapidly, because larvae must contact or ingest treated tissue before feeding stops. This distinction is important when interpreting attack incidence alongside current larval abundance (Bagariang et al., 2020).

Table 2. Effect of Various Insecticides on the Intensity of *Spodoptera frugiperda Attacks*

Treatment	Attack Intensity (%)				
	20 DAP	27 DAP	34 DAP	41 DAP	48 DAP
Control (A)	53.33 ± 1.67 b	63.33 ± 1.67 b	70.00 ± 2.89 b	78.33 ± 6.67 a	86.67 ± 1.67 a
Chlorantraniliprole (B)	36.67 ± 1.67 a	50.00 ± 2.89 b	58.33 ± 1.67 a	60.00 ± 2.89 a	60.00 ± 2.89 a
Cyantraniliprole (C)	41.67 ± 4.41 a	48.33 ± 1.67 a	63.33 ± 4.41 a	65.00 ± 2.89 a	66.67 ± 1.67 a
Emamectin Benzoate (D)	31.67 ± 1.67 a	36.67 ± 1.67 a	53.33 ± 4.41 a	66.67 ± 6.67 a	71.67 ± 9.28 a
Indoxacarb (E)	33.33 ± 4.41 a	38.33 ± 4.41 a	50.00 ± 5.00 a	55.00 ± 5.00 a	71.67 ± 7.26 a
Methomyl (F)	28.33 ± 3.33 a	41.67 ± 1.67 a	50.00 ± 2.89 a	66.67 ± 10.14 a	71.67 ± 10.14 a
Cypermethrin (G)	30.00 ± 2.89 a	35.00 ± 2.89 a	51.67 ± 7.26 a	63.33 ± 9.28 a	68.33 ± 12.02 a
Chlorpyrifos (H)	35.00 ± 2.89 a	43.33 ± 1.67 a	46.67 ± 1.67 a	51.67 ± 1.67 a	55.00 ± 2.89 a
Fipronil (I)	26.67 ± 1.67 a	51.67 ± 1.67 b	48.33 ± 6.67 a	55.00 ± 7.64 a	66.67 ± 8.33 a
P-value	< 0.001	< 0.001	0.019	*0.144*	*0.293*

Note: Values are presented as Mean ± Standard Error (SE). Means followed by the same letter within a column are not significantly different according to the Scott-Knott test at $\alpha = 0.05$.

Damage Incidence (%)

Damage intensity changed across assessments at 20, 27, 34, 41, and 48 DAP. Treatment differences reflected variation in the ability of the tested insecticides to limit further leaf injury. Damage may accumulate from the vegetative into the generative stage because larvae continue feeding on newly developing corn tissue (Wilyus *et al.,* 2022) (Table 3).

Damage intensity in the untreated control rose from 15.42% at 20 DAP to 38.33% at 48 DAP. Larvae sheltered in the whorl can feed on rolled leaves, producing longitudinal tears as the leaves expand. Extensive injury reduces functional leaf area and may damage the growing point, thereby constraining cob development (Maharani et al., 2019). At 48 DAP, chlorpyrifos (13.75%), chlorantraniliprole (15.42%), and cyantraniliprole (17.50%) were associated with the lowest reported damage values.

Differences in damage suppression may be related to how quickly feeding ceases after exposure. Chlorantraniliprole and cyantraniliprole have systemic or translaminar activity and can affect larvae feeding within protected plant tissues (Pes et al., 2020). Rapid paralysis limits additional tissue removal even when earlier feeding marks remain visible. Chlorpyrifos also produced low damage under the conditions of this trial, consistent with its rapid neurotoxic action (Soliman, 2025).

Table 3. Effect of Various Insecticides on the Intensity *of Spodoptera frugiperda Damage*

Treatment	Damage Intensity (%)				
	20 DAP	27 DAP	34 DAP	41 DAP	48 DAP
Control (A)	15.42 ± 0.42 b	20.00 ± 0.00 b	24.17 ± 2.53 b	30.42 ± 0.42 b	38.33 ± 0.42 b
Chlorantraniliprole (B)	9.17 ± 0.42 a	12.50 ± 0.72 a	14.58 ± 0.42 a	15.00 ± 0.72 a	15.42 ± 0.42 a
Cyantraniliprole (C)	10.83 ± 0.83 b	12.92 ± 0.42 a	16.67 ± 1.50 a	17.08 ± 1.10 a	17.50 ± 0.72 a
Emamectin Benzoate (D)	7.92 ± 0.42 a	9.17 ± 0.42 a	13.33 ± 1.10 a	16.67 ± 1.67 a	17.92 ± 2.32 a
Indoxacarb (E)	9.17 ± 0.42 a	15.00 ± 1.44 b	19.17 ± 0.42 b	22.92 ± 0.42 a	27.08 ± 1.67 a
Methomyl (F)	7.08 ± 0.83 a	11.25 ± 0.72 a	13.75 ± 1.44 a	17.92 ± 3.25 a	19.58 ± 3.63 a
Cypermethrin (G)	7.50 ± 0.72 a	10.42 ± 1.67 a	19.57 ± 2.21 b	25.00 ± 3.15 b	28.33 ± 4.35 b
Chlorpyrifos (H)	8.75 ± 0.72 a	10.83 ± 0.42 a	12.08 ± 0.42 a	12.92 ± 0.42 a	13.75 ± 0.72 a
Fipronil (I)	7.13 ± 0.44 a	12.92 ± 0.42 b	14.17 ± 0.42 a	17.08 ± 1.67 a	21.25 ± 3.31 a
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Note: Values are presented as Mean ± Standard Error (SE). Means followed by the same letter within a column are not significantly different according to the Scott-Knott test at $\alpha = 0.05$.

Cob Weight with Husk per Plant and per Plot (g)

Analysis of variance detected a treatment effect on cob weight with husk, measured both per plant and per plot. Treatment means are presented in Table 4.

Cob weight with husk differed among treatments. The untreated control and cypermethrin treatment formed the lowest statistical group, yielding 293.27 and 294.40 g plant−1, respectively, or 1,466.33 and 1,472.00 g plot−1. Lower yield in the control coincided with greater attack incidence and leaf damage. The same yield response under cypermethrin indicates comparatively weak field performance of that treatment.

Because leaves supply assimilates for grain filling, defoliation can reduce the photosynthetic area available to support cob development (Maharani et al., 2019). The low

performance of cypermethrin should be described as reduced field efficacy; resistance cannot be concluded without a susceptibility bioassay or diagnostic-dose comparison. Chlorantraniliprole, cyantraniliprole, emamectin benzoate, indoxacarb, and methomyl formed the higher-yield statistical group, with reported cob weights of 382.87–389.73 g plant−1.

Cob Weight without Husk per Plant and per Plot (g)

A significant treatment effect was also detected for cob weight without husk at both the plant and plot levels. Treatment means are provided in Table 5.

The response of unhusked cob weight was comparable to that observed for cobs with husks. The control and cypermethrin treatments produced the lowest values, 212.73 and 214.27 g plant−1, respectively. Higher means were recorded for emamectin benzoate (282.67 g plant−1), indoxacarb (282.87 g plant−1), and chlorantraniliprole (281.40 g plant−1). Suppression of larvae within folded leaves and whorls likely helped preserve the foliage needed for cob filling (Bersinar et al., 2021).

Table 4. Effect of Insecticide Treatment on Cob Weight with Husk (g)

Treatment	Weight of Cob with Husk (g)	
	Per plant	Per plot
Control (A)	293.27 ± 1.07 a	1466.33 ± 5.36 a
Chlorantraniliprole (B)	389.27 ± 0.37 b	1946.33 ± 1.86 b
Cyantraniliprole (C)	386.93 ± 1.46 b	1934.67 ± 7.31 b
Emamectin Benzoate (D)	389.13 ± 1.80 b	1945.67 ± 9.02 b
Indoxacarb (E)	389.73 ± 0.75 b	1948.67 ± 3.76 b
Methomyl (F)	382.87 ± 6.75 b	1914.33 ± 33.75b
Cypermethrin (G)	294.40 ± 0.50 a	1472 .00 ± 2.52 a
Chlorpyrifos (H)	382.87 ± 5.62 b	1914.33 ± 28.11 b
Fipronil (I)	387.87 ± 1.09 b	1939.33 ± 5.46 b
P-value	< 0.001	< 0.001

Note: Values are presented as Mean ± Standard Error (SE). Means followed by the same letter within a column are not significantly different according to the Scott-Knott test at α = 0.05.

Table 5. Effect of Insecticide Treatment on Cob Weight without Husk (g)

Treatment	Weight of Corn Without Husk (g)	
	Per plant	Per plot
Control (A)	212.73 ± 1.67 a	1063.67 ± 8.37 a
Chlorantraniliprole (B)	281.40 ± 0.92 b	1407.00 ± 4.58 b
Cyantraniliprole (C)	280.13 ± 3.06 b	1400.67 ± 15.30 b
Emamectin Benzoate (D)	282.67 ± 1.92 b	1413.33 ± 9.61 b
Indoxacarb (E)	282.87 ± 2.29 b	1414.33 ± 11.46 b
Methomyl (F)	281.47 ± 2.60 b	1407.33 ± 13.02 b
Cypermethrin (G)	214.27 ± 0.90 a	1071.33 ± 4.48 a
Chlorpyrifos (H)	281.80 ± 2.25 b	1409.00 ± 11.27 b
Fipronil (I)	278.67 ± 1.99 b	1393.33 ± 9.94 b
P-value	< 0.001	< 0.001

Note: Values are presented as Mean ± Standard Error (SE). Means followed by the same letter within a column are not significantly different according to the Scott-Knott test at α = 0.05.

Insecticide Effectiveness (%)

Estimated insecticide efficacy varied among treatments and assessment dates. Most sections identify 20, 27, 34, 41, and 48 DAP, whereas this section and Table 6 refer to 20, 27, 34, 42, and 49 DAP. The correct schedule must therefore be verified from the field records. Overall, efficacy tended to increase during the observation period, consistent with greater suppression of the treated populations relative to the control (Darmawan Septian et al., 2021).

Efficacy (EI) expresses the proportional reduction in larval abundance in a treated plot relative to the untreated control. In this study, values above 50% were interpreted as effective. At the first assessment, chlorantraniliprole (B) and indoxacarb (E) each had a reported efficacy of 41.67%. Their subsequent increase may reflect differences in exposure, uptake, and feeding behavior; however, application timing and formulation data are needed before the cause of the delayed response can be established.

Several treatments, including chlorantraniliprole, cyantraniliprole, emamectin benzoate, methomyl, and chlorpyrifos, reached a calculated efficacy of 100% at the final assessment because no larvae were recorded in the treated plots. This endpoint indicates complete suppression at that observation, but it does not by itself identify a uniquely superior treatment. Selection for field use should also consider residual performance, registered use, preharvest interval, operator safety, non-target organisms, cost, and resistance management.

Table 6. Effectiveness of Various Insecticides in Controlling *Spodoptera frugiperda Pests*

Treatment	Insecticide Effectiveness				
	20 DAP	27 DAP	34 DAP	41 DAP	48 DAP
Chlorantraniliprole (B)	41.67	60.00	72.73	100.00	100.00
Cyantraniliprole (C)	58.33	45.00	100.00	100.00	100.00
Emamectin Benzoate (D)	50.00	75.03	96.97	100.00	100.00
Indoxacarb (E)	41.67	55.00	93.94	95.74	100.00
Methomyl (F)	66.67	55.00	100.00	100.00	100.00
Cypermethrin (G)	75.00	10.00	39.39	89.36	98.53
Chlorpyrifos (H)	54.17	50.00	100.00	100.00	100.00
Fipronil (I)	66.67	10.00	87.88	91.49	98.53

CONCLUSION

Under the conditions of this field experiment, insecticide treatment reduced fall armyworm abundance, attack incidence, and damage severity and improved cob weight relative to the untreated control. Several active ingredients produced 100% calculated efficacy at the final assessment. The available results do not support selecting a single best product from final efficacy alone. Before submission, the authors should verify the assessment dates and Table 6 labels and complete the descriptions of product dose, application procedure, sampling unit, and statistical analysis.

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