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Field efficacy of selected insecticides and botanicals against fall armyworm in maize

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Abstract
In Bangladesh's northern and western regions, where maize (*Zea mays* L.) crops were already under threat from other pressures, particularly those brought on by climate change, the invasion of the fall armyworm [*Spodoptera frugiperda* (J.E. Smith); FAW] has compounded yield losses. From the present study, it was observed that application of the synthetic insecticides Ripcord 10 EC (Cypermethrin), Karate 2.5 EC (Lamda Cyhalothrin), Nitro 505 EC (Chlorpyrifos 50% + Cypermethrin 5%), Virtako 40 WG (Thiamethoxam 20% + Chlorantraniliprole 20%) and Neem Seed kernel Extract (Azadirachtin) compared to the untreated control, was effective and dramatically enhanced FAW larval mortality, decreased leaf degradation, and boosted biomass in maize. In the first round of spraying, both stay living larvae were identified on plants treated with Ripcord 10 EC (Cypermethrin), and in the second round of spraying; no live larvae were found on plants treated with Karate 2.5 EC (Lamda Cyhalothrin). After the third round of spraying, below one larva was found on all treated plants. The most effective synthetic pesticides are therefore recommended Ripcord 10 EC (Cypermethrin) and Karate 2.5 EC (Lamda Cyhalothrin) for the control of FAW in maize which will be planted in November-December in Bangladesh.

Keywords: Field efficacy, insecticides, botanicals, fall armyworm, management

Introduction
In Bangladesh, maize is one of numerous cereal crops that are farmed [2]; it is also one of the most significant. Zea mays, or maize, is a superior crop for use in food, feed, and industry [4, 21]. It is significant globally as a cash crop and a source of sustenance, especially for small farmers [9, 15, 25]. The United States (which produces over 40% of the world's maize) is the pioneer in this field [23]. Maize has a huge commercial potentiality [31]. In Bangladesh, maize is planted twice a year (in the spring and the fall) [26]. The need for maize is rising in Bangladesh for both the food supply for the populace and the poultry and fish industries [1]. Only 70% of the 1.8 million tons of maize that are used annually are cultivated in the state; the remainder is imported from other countries [20]. More than 90% of maize is used to feed poultry, as a byproduct in fish farming, and to make food for humans [18, 29]. In emerging countries like Bangladesh, the production and demand for maize have both increased by 2050 [30, 14]. Daily demand for maize for animal feed has increased [7, 24]. This has been greatly influenced by the quick commercial expansion of the poultry and livestock industries in Asia's densely populated areas [13].

An estimate states that 10% of the maize produced in Bangladesh is used to feed fish, 5% is used as fodder, and the remaining 85% is utilized in the poultry industry. But the nation can only meet 70% of its whole demand. Despite the fact that the area planted with this crop has increased, its productivity is still very poor for a variety of reasons, including environmental variables, a lack of automation, pests and diseases, etc. [27]. In Bangladesh, one of the major causes of this shortage of maize production is drought and drought induced insect pest's attack. The insect pests that attack maize cause significant losses both directly (as borers, sap suckers, stem and root feeders, etc.) and indirectly (as disease vectors). Therefore, adaptive measures to climate change must be taken as a main concern in this crop management for ensuring the food security under changing climate [19].

From planting to harvest, up to 141 insect pests inflict varied degrees of damage on maize crops [27]. The findings of BARI's 2006 study indicated that 10 insects attacked maize. Fall Armyworm is one of the insect pests that cause a lot of concern in South and Southeast Asia because of the hot, humid climate there. Due of the prolonged summer, South Asian nations including India, Bangladesh, Pakistan, and Sri Lanka are more susceptible to an armyworm outbreak in the fall. Fall Armyworm (FAW), a species of *Spodoptera frugiperda*, has decimated millions of square kilometers of maize and sorghum fields and severely damaged the livelihoods of farmers in Africa and India. It likes maize but can eat more than 80 different plant species, including cotton, rice, sorghum, millet, sugarcane, and vegetable crops. The caterpillar, a severe threat to maize farming in Bangladesh, has lately been found in cabbage fields in Rangpur, Thakurgaon, Bogura, and Jashore as well as in fields of maize in Bogura and Chuadanga. In a field survey of maize, the rate of field infestation by fall armyworm was found 70.83% in barind areas of Bangladesh [32]. Therefore, the current study has planned to observe the pest status of fall armyworm with their damage potential under supervised field trial of maize as well as to develop improved management practices against fall armyworm.

Materials and methods

Study site and climatic conditions

The study was carried out in Gazipur, Bangladesh, at 25°25′ North latitude and 89°5′ East longitude, in the Field and Laboratory of the Department of Entomology of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), from October 2021 to August 2022. The region represents the agro-ecological zone of the Madhupur tract (AEZ-28), where silty clay loam, silt loam, clay loam, silty clay, and clay are the most common soil textural classes. The pH ranges from 5.8 to 6.5 and is extremely acidic to mildly acidic. The research area experiences a tropical environment with seasonal variations, with a clear dry season (February to May), rainy season (June to September), and brief winter (December and January). Maximum and minimum temperatures, relative humidity, and rainfall are all of the order of 36.0 and 12.7 °C, 65.8% and 237.6 cm annually [5].

Experimental materials and design

BHM-09 variety of maize was selected for cultivation. Three replications of each treatment were used in the field experiment, which was set up using a Randomized Complete Block Design (RCBD). The unit plot measured 3 m × 3 m, and the plant to plant and row to row distances were each 75 cm. The crop was grown in the experimental field with the application of fertilizers at recommended doses [17].

Table 1: List of synthetic insecticides used in the trial against FAW, together with their active ingredients (a.i.) and recommended label rates.

Trade Name	Active Ingredient	Manufacturer	Dosage
Nitro 505 EC	Chlorpyrifos 50% + Cypermethrin 5%	Auto crop care ltd.	1ml/ liter water
Virtako 40 WG	Thiamethoxam 20% + Chlorantraniliprole 20%	Syngenta	1g/ liter water
Karate 2.5 EC	Lamda Cyhalothrin	Syngenta	2g/kg seed
Ripcord 10 EC	Cypermethrin	BASF Bangladesh ltd.	1ml/ liter water
Atchta 1% EC	Azadirachtin	Haychem	2 ml/liter water
Pheromone trapping	Sordidin mixed with isoamyle acetate.	Ispahani Agro Ltd. BD and Russell IPM Ltd., UK	70traps/ha

Treatments

Treatment 01: Nitro 505 EC (Chlorpyrifos 50% + Cypermethrin 5%) @ 1ml/l of water.
Treatment 02: Virtako 40 WG (Thiamethoxam 20% + Chlorantraniliprole 20%) @ 1g/l of water.
Treatment 03: Neem Seed kernel Extract (Azadirachtin) @ 50 g/l of water.
Treatment 04: Collection of adult moths by pheromone trapping (pheromone lures collected from Ispahani Agro Ltd. BD and Russell IPM Ltd., UK) [3].
Treatment 05: Seed Treatment with Karate 2.5 EC (Lamda Cyhalothrin) @ 2g/kg seed + Mechanical control (Hand picking and clean cultivation)
Treatment 06: Ripcord 10 EC (Cypermethrin) @ 1ml/l of water + Mechanical control (Hand picking and clean cultivation) + Collection of adult moths by pheromone trapping
Treatment 07: Seed Treatment with Karate 2.5 EC (Lamda Cyhalothrin) @ 2 g/kg seed + Mechanical control (Hand picking and clean cultivation) + Collection of adult moths by pheromone trapping
Treatment 08: Untreated control

Assessment of fall armyworm infestation

For assessment of insect infestation, data collections were started from the first sign of infestation, and were continued until final harvest of maize. Number of infested leaves and cobs was counted and converted into percent leaf and cob infestation using following formula-

$$\text{Fresh leaf infestation (\%)} = \frac{\text{Number of infested leaves}}{\text{Total number of leaves}} \times 10$$

$$\text{Cob infestation (\%)} = \frac{\text{Number of infested Cobs}}{\text{Total number of Cobs}} \times 10$$

Observation of live larvae in field condition

For the observation of live larvae, data collections were started from the first sign of infestation, and were continued until final harvest of maize. The quantities of live larvae, dead larvae, and pupae in the treated plants and the untreated control plants were tallied beginning with the first indication of infestation and continuing for seven days after each application of synthetic insecticide.

Calculation of yield

Marketable grain yield from treated and untreated control plants was measured, aggregated, and represented in kg per hectare.

Statistical analysis

To ascertain the effects of insecticides on morphological traits, leaf and cob damage percentage, mean larval mortality, and yield of maize, one way analysis of variance (ANOVA) followed by Tukey HSD posthoc test (at 5% level of significance) was conducted. The statistical software package

IBM SPSS 20.0 was used for data analysis.

Results and Discussion

In comparison to the untreated control, the number of live larvae was decreased after being sprayed with various treatments (unsprayed plants). Plants treated with Ripcord 10 EC (Cypermethrin) (T_6) and Virtako 40 WG displayed considerably (F = 23.88; DF = 5; p 0.001) less live larvae during the initial spraying. In comparison to the control (unsprayed plants), the number of live larvae was considerably reduced in all treated plants in the second (F = 7.35; DF = 5; p = 0.003) and third (F = 7.5; DF = 5; p = 0.002) round sprays (Table 1). In addition, no live larvae were found on plants treated with Ripcord 10 EC (Cypermethrin) (T_6) in the second round of spraying, and no such larvae were found on plants treated with Ripcord 10 EC (Cypermethrin) and Karate 2.5 EC in the third round of spraying.

Table 2: Efficacy of different insecticides against live larvae of fall armyworm on maize under field conditions in December planted Maize crop 2021

Treatments	Mean no of Live larvae (± SEM)			
	Pre-Spray	Spray 1	Spray 2	Spray 3
T_1	5±1.5a	2.2±0.0b	0.9±0.3bc	0.2±0.0b
T_2	4.8±1.2a	1.2±0.03c	0.7±0.0cd	0.4±0.0b
T_3	3.5±0.15a	2.2±0.2bc	1.1±0.3bc	0.4±0.0b
T_4	3.5±0.27a	2.9±0.15ab	1.8±0.15b	0.6±0.0b
T_5	5±1.08a	2.2±0.02b	0.6±0.02cd	0±0.0b
T_6	4.5±0.15a	1.2±0.0c	0d	0±0.0b
T_7	3.9±0.18a	1.5±0.1c	0.8±0.2bc	0±0.0b
Control	4.5±0.15a	5±0.15a	5.2±0.6a	5.9±0.23a
ANOVA				
F =	1.0	23.88	7.35	7.5
DF =	5	5	5	5
P =	0.57	0.00	0.003	0.002

[Treatment 01: Nitro 505 EC (Chlorpyrifos 50% + Cypermethrin 5%) @ 1ml/l of water, Treatment 02: Virtako 40 WG (Thiamethoxam 20% + Chlorantraniliprole 20%) @ 1g/l of water, Treatment 03: Neem Seed kernel Extract (Azadirachtin) @ 50 g/l of water, Treatment 04: Collection of adult moths by pheromone trapping (pheromone lures collected from Ispahani Agro Ltd. BD and Russell IPM Ltd., UK) [3], Treatment 05: Seed Treatment with Karate 2.5 EC (Lamda Cyhalothrin) @ 2 g/kg seed + Mechanical control (Hand picking and clean cultivation), Treatment 06: Ripcord 10 EC (Cypermethrin) @ 1 m l/l of water + Mechanical control (Hand picking and clean cultivation) + Collection of adult moths by pheromone trapping, Treatment 07: Seed Treatment with Karate 2.5 EC (Lamda Cyhalothrin) @ 2 g/kg seed + Mechanical control (Hand picking and clean cultivation) + Collection of adult moths by pheromone trapping, Treatment 08: Untreated control].

Every round of spraying resulted in a considerable difference in the amount of leaf damage caused by FAW larvae. Comparatively to plants treated with synthetic insecticides, the control plants that weren't treated suffered significant leaf damage from FAW larvae (Figure 1). Karate 2.5 EC-treated plants showed the least amount of leaf damage after the third round of spraying, while Virtako 40 WG-treated plants showed the most (Figure 1).

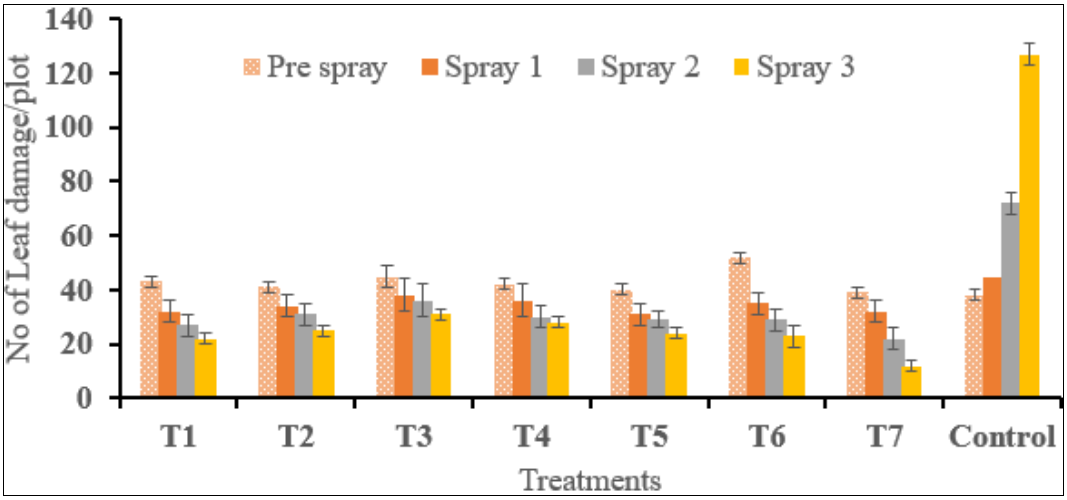

Fig 1: Mean (± SEM) of leaf damage of maize by FAW under different treatments in the field

Plant height, stem thickness, leaf count, and dry matter did not significantly differ between treatments in maize plants. The fresh weight, however, varied significantly between treatments (F = 3.16; DF = 9; p = 0.015). The plants treated with Karate 2.5 EC produced the maximum fresh weight (472 g) (Table 1).

Table 3: Mean percentage (± SEM) of plant height, stem thickness, leaf number, fresh and dry weight of maize under different treatments in December planted Maize crop 2021.

Treatments	Plant Height (cm)	Stem Thickness (cm)	Leaf number	Fresh Weight (gm.)	Dry weight (gm.)
T1	171.7±13.7	21.4±0.20	15.7±0.88	400±28.2ab	75±6.06
T2	149.3±10.1	19.1±1.64	14±0.57	302±13.6 ab	73±7.44
T3	162.7 ±3.33	20±1.25	14.7±0.67	335±25.8 ab	67±10.1
T4	162.7±3.33	19.5±1.45	14.3±0.88	327±22.4 ab	78±16.5
T5	166.7±8.33	20.5±1.10	14.7±0.33	374±37.6 ab	69±7.91
T6	171.0±17.6	20.5±2.13	15.3±1.20	397±49 ab	96±14.6
T7	173.3±3.33	23±2.13	16±1	472±43.9 a	87±14.1
Control	113.3±25.2	14.8±1.92	13.3±1.67	167±20.3 b	23±1.99
ANOVA					
F =	2.08	1.48	0.89	3.16	2.37
DF =	9	9	9	9	9
P =	0.083	0.220	0.552	0.015	0.052

[Treatment 01: Nitro 505 EC (Chlorpyrifos 50% + Cypermethrin 5%) @ 1ml/l of water, Treatment 02: Virtako 40 WG (Thiamethoxam 20% + Chlorantraniliprole 20%) @ 1g/l of water, Treatment 03: Neem Seed kernel Extract (Azadirachtin) @ 50 g/l of water, Treatment 04: Collection of adult moths by pheromone trapping (pheromone lures collected from Ispahani Agro Ltd. BD and Russell IPM Ltd., UK) [3], Treatment 05: Seed Treatment with Karate 2.5 EC (Lamda Cyhalothrin) @ 2g/kg seed + Mechanical control (Hand picking and clean cultivation), Treatment 06: Ripcord 10 EC (Cypermethrin) @ 1ml/l of water + Mechanical control (Hand picking and clean cultivation) + Collection of adult moths by pheromone trapping, Treatment 07: Seed Treatment with Karate 2.5 EC (Lamda Cyhalothrin) @ 2 g/kg seed + Mechanical control (Hand picking and clean cultivation) + Collection of adult moths by pheromone trapping, Treatment 08: Untreated control].

Every round of spraying resulted in a considerable difference in the amount of cob damage caused by FAW larvae. Comparatively to plants treated with synthetic insecticides, the control plants that weren't treated suffered significant cob damage from FAW larvae (Figure 2). The plants treated with Ripcord 10 EC and Nitro 505 EC showed the least cob damage after the third session of spraying, while adult moth pheromone trapping revealed the most severe cob damage (Figure 2).

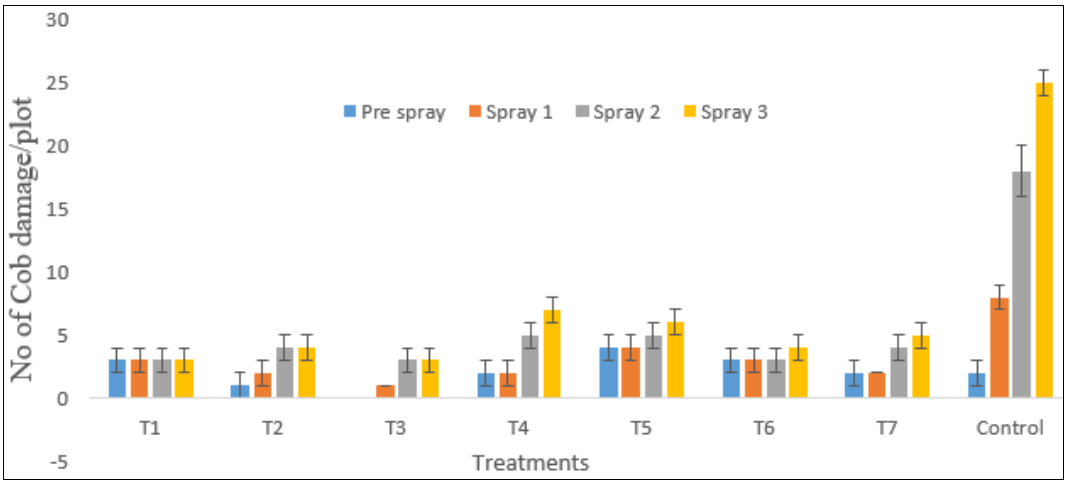

Fig 2: Mean (± SEM) of cob damage of maize by FAW under different treatments

Ripcord 10 EC (Cypermethrin) treated plot was recorded the higher grain yield of 6296 kg per ha, which was significantly similar to Karate 2.5 EC (Lamda Cyhalothrin) 6173 kg per ha (Fig. 3). The next most efficient treatments were Nitro 505 EC (Chlorpyrifos 50% + Cypermethrin 5%), Virtako 40 WG (Thiamethoxam 20% + Chlorantraniliprole 20%) and Neem Seed kernel Extract (Azadirachtin) which recorded yield was of 5988, 5926 and 5864 kg per ha respectively. The control showed a reduction of yield in comparison with the best insecticide treatment (Cypermethrin). In the December planted crop, the most effective insecticides were Cypermethrin and Lamda Cyhalothrin, followed by (Chlorpyrifos 50% + Cypermethrin 5%), (Thiamethoxam 20% + Chlorantraniliprole 20%) and Azadirachtin.

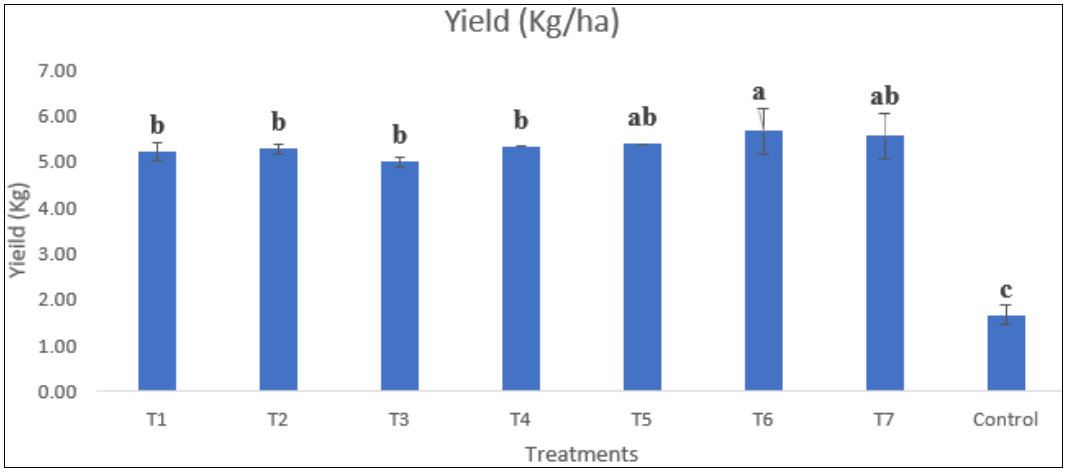

Fig 3: Mean (± SEM) yield of maize under different treatments

Discussion

All of the synthetic insecticides evaluated in this study were toxic to FAW larvae, and some of them showed substantial larval mortality in field tests. The study's findings showed a considerable decrease in leaf damage to maize compared to the control, which is explained by the fewer larvae present in the treated plants. In contrast to untreated control plants, plants treated with synthetic pesticides produced the highest fresh and dry weights. Synthetic pesticides are significant management alternatives for FAW control in the Americas, as is typical for other insect pest species [6]. Methyl parathion, chlorpyrifos, methamidophos, and phoxim, among other synthetic insecticides, are applied in Mexico to suppress FAW in maize [22]. In the southeast, synthetic insecticides are frequently used three to four times each week to sweet corn to protect it from FAW. One of the most significant sweetcorn pests in Florida is FAW, which is controlled with synthetic insecticides to safeguard both the vegetative and reproductive stages of corn [10]. To destroy larvae eating deeply within the whorl of plants, several insecticide applications are necessary. The quantity of sprayings required during the silking stage may be decreased by keeping plants larvae-free during the vegetative period [16]. The results of the present investigation are supported by some of the synthetic pesticides mentioned by those authors. For instance, Belay *et al*. (2012) [8] showed that 16 hours after applying Radiant, Orthene, and Larvin, more than 60% of FAW mortality had occurred. In a different investigation, Intrepid 2F, Lannate 2.4LV, Sevin XLR Plus 4F, and Tracer 4SC significantly decreased FAW larvae in the field [12]. The effectiveness of locally accessible insecticidal herbs against FAW larvae varied in the current investigation. Silva *et al*. (2015) found increased larval mortality of FAW using an A. indica seed cake extract, which is consistent with the findings of the current investigation. In additional investigations, Boldo and P. boldus Molina exhibited repelling qualities at high concentrations and produced toxicity by acting as a feeding inhibitor [28]. Larval mortality was brought on by extracts of Cedrela salvadorensis and C. dugesii [11]. One of the hardest pests to manage in Bangladesh is FAW due to its capacity to reproduce more than once, travel, and feed on a variety of host plants. Bangladesh's maize output is being threatened by FAW. To combat the FAW pest threat and prevent economic hardship for Bangladesh's smallholder farmers, swift and coordinated action, massive awareness raising, technical innovation, and national, regional, and worldwide collaboration are all necessary. It is necessary to develop and implement an efficient integrated pest management strategy that can offer long-term solutions to effectively combat the negative consequences of FAW. Therefore, the current study aids in the control of the FAW in the selection of potent synthetic pesticides.

Conclusion

From the present study, it was observed that application of the synthetic insecticides Ripcord 10 EC (Cypermethrin), Karate 2.5 EC (Lamda Cyhalothrin), Nitro 505 EC (Chlorpyrifos 50% + Cypermethrin 5%), Virtako 40 WG (Thiamethoxam 20% + Chlorantraniliprole 20%) and Neem Seed kernel Extract (Azadirachtin) compared to the untreated control, was effective and dramatically enhanced FAW larval mortality, decreased leaf damage, and boosted biomass in maize. Plants treated with Ripcord 10 EC produced no live larvae (Cypermethrin). Additionally, in the combination of treatments, following the second round of spraying with Karate 2.5 EC (Lamda Cyhalothrin), no live larvae were found on plants treated, while less than one larva was found on all treated plants. For the treatment of FAW in maize that will be grown in Bangladesh in November-December, Ripcord 10 EC (Cypermethrin) and Karate 2.5 EC (Lamda Cyhalothrin) are advised as the most effective synthetic pesticides. Long-term FAW resistance to insecticides may result from sole reliance on chemical control. Therefore, to combat FAW, we should utilize such pesticides in integrated pest management techniques.

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