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# LETHAL AND SUBLETHAL EFFECT OF SWEET BASIL (*OCIMUM BASILICUM*) AGAINST MAIZE FALL ARMYWORM (*SPODOPTERA FRUGIPERDA*)

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**A B S T R A C T**

The fall armyworm (*Spodopterafrugiperda*; Lepidoptera: Noctuidae) is a destructive pest of maize and several other crops, causing significant yield losses worldwide. Due to the environmental and resistance issues associated with synthetic insecticides, eco-friendly alternatives such as plant-based extracts are being explored. This study was conducted during 2025–26 at the Laboratory of Plant Protection, Department of Plant Protection, Faculty of Crop Protection, Sindh Agriculture University, Tando Jam, to evaluate the lethal and sub-lethal effects of sweet basil (*Ocimumbasilicum*) extract against fall armyworm larvae under laboratory conditions using a Completely Randomized Design (CRD) with three replications. Four concentrations of sweet basil extract (10, 25, 75, and 100 ml $L^{-1}$) along with a control were tested against 3rd and 4th instar larvae. Larval mortality was recorded at 1, 3, 5, and 7 days after treatment, and data were analyzed using ANOVA with mean comparison through LSD at $P \leq 0.05$. The results showed a clear dose- and time-dependent response, with mortality increasing as extract concentration and exposure duration increased. The highest mortality (91.63 ± 16.69%) was recorded at 100 ml on the 7th day, while the lowest mortality (25.15 ± 3.25%) was observed at 10 ml. No mortality was recorded in the control, confirming that larval death was due to the extract. In addition to lethal effects, significant sub-lethal effects were observed. Larval and pupal durations were prolonged with increasing concentrations, indicating delayed development due to physiological stress and metabolic disruption. In contrast, larval and pupal weights decreased significantly with increasing extract concentration, suggesting reduced feeding and impaired nutrient assimilation. These combined effects negatively influence insect growth, survival, and potential reproduction. Overall, the findings demonstrate that *O. basilicum* extract possesses strong larvicidal and growth-inhibiting properties against *S. frugiperda*. Therefore, it can be considered a promising eco-friendly alternative to synthetic insecticides and may be effectively incorporated into integrated pest management programs for sustainable control of fall armyworm in maize.

**Keywords:** *Eco-friendly management, Fall armyworm, Lethal, Sub-lethal effects.*

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## INTRODUCTION

In Pakistan, maize (*Zea mays* L.), a member of the Gramineae family, is one of the most important cereal crops after rice and wheat (Bukhsh et al., 2021). The maize crop is utilized all over the world for both food and feed. It contains high-value food for humans as well as stockpiles for animal feed (Abebe&Feyisa, 2017; Adnan & Bilal, 2020). The maize crop is being attacked by numerous insect pest species, for example whitefly, leaf lopper, and non-insect pest, red spider mite from these insect pests the fall

armyworm is the serious and most noxious insect pest of the maize crop. This insect pest is found from all maize cultivation zones of the world. Fall armyworm mostly found attacking on all development stages, usually 60-90 % damage occur due to this insect pest (Arif et al., 2012). Maize crop is attacked by a lepidopteron insect called fall armyworm which causes extensive damage to the growing shoot tips and fruits, due to attack of this insect pest the quantity and maize's quality was negatively impacted. Its mode of damage is that first burrow in the fruit and then start to eat inside the fruit, so after entering the fruit it is very difficult to manage (Martinez et al., 2019).

The various factors involved in low maize production in Pakistan. Maize crop is infested by several insect pests such as fall armyworm (*Spodoptera frugiperda*), stem borer (*Chilopartellus*), shoot fly (*Atherigona soccata*) are main pest causing significant losses (Nabeel et al., 2018). Among all insect pests, *S. frugiperda* is one of the main destructive and serious pests for maize (Assefa & Ayalew, 2019). The *S. frugiperda* is reported on 353 host plants in 76 families (Montezano et al., 2018). Fall Armyworm originated in the United States, but recent reports from the Asia Pacific and Africa. The *S. frugiperda* has raised serious concerns around the world, its destruction in Asia in 2018 and Africa in 2016 (Deshmukh et al., 2021). Its damage has been reported from more than 80 crops such as maize, millet, rice, sugarcane, millet, and cotton being the main hosts of fall armyworm (Abrahams et al., 2017). Younger larvae feed on leaf tissue, while older larvae cause severe degeneration. It is also suppressed in growing places (twigs, circles, etc.), causing the "dead heart", withering and spreading leaves to die. The most severe damage is caused by eating larvae inside the fruit, while boredom inside the shoots causes damage shoots and causes crop about 15-73% (Lima et al., 2010).

The *S. frugiperda* larvae is responsible in the maize fields to decrease in maize yield. Yield reduction in rice was correlated with larval density within the maize fields (Cruz, 2019). The dangerous stage of *S. frugiperda* is the larvae because the first and second instars usually consume one side of the leaves and make them into skeletons, while the last instars eat all parts of their hosts (Abrahams et al., 2017). Research revealed that due to the attack of *S. frugiperda* producing output losses of up to 100% if it is not properly handled (Michelotto et al., 2011). There are various methods of control that have posed many problems including insecticide resistance, resurgence of insect pests, biotype development and environmental hazards (Rasool et al., 2017). The rapid development of resistance to various insecticide groups, the ongoing requirement to rotate insecticide mechanisms of action, and the use of insecticides for the various stages of the pest are some of the challenges facing the effective chemical control of this pest (Castle et al., 2010).

Natural insecticides can help address these issues while lessening the negative effects of traditional pesticides on beneficial insects and human health during food production. Terpenoids are a rich source of bioactive molecules that are harmful to a variety of pests, among the substances produced by plants' secondary metabolism (Lima et al., 2013). According to some research, these substances function as AChE inhibitors, disrupt cellular respiration, oviposition and work in concert with other bioactive substances (Fazolin et al., 2016). A terpenoid called linalool functions in conjunction with other substances in the insect cholinergic system and may indirectly modulate acetylcholinesterase. One of the main natural sources of linalool is *O. basilicum* (Lamiaceae), which contains the terpenoid in over 80% of its essential oil on average. According to its range of toxicity, linalool demonstrated promise in suppressing *S. frugiperda* through a knockdown effect, acute toxicity, repellant effect, and non-preference (Radhika & Sahayaraj, 2014).

Researchers have recently highlighted the significance of product synergism, such as the correlation between natural and synthetic compounds (Radhika & Sahayaraj, 2014) with the primary goal of lowering the quantity of a pesticide required to produce the same toxic effect. Additionally, compared to their solo use, insecticides can become more harmful when combined (Khann et al., 2013). An excellent illustration of this combination is a blend of terpenoids called pyrethroid, safrole, and rotenone, which are known to block cytochrome P450, the primary pathway for pesticide metabolism (Fazolin et al., 2016). Terpenoids and pyrethroids have different chemical structures and modes of action, they are less harmful to mammals and other beneficial organisms and induce similar toxicity in pests.

However, recently study documented that the essential oil of *O. basilicum* commonly known as Niazboo exhibits the insecticidal properties against the *S. frugiperda*, which is a significant pest of maize crops (Jafir et al., 2021), have shown that Niazboo essential oil, particularly its major components like linalool and 1, 8-cineole, can be toxic to FAW larvae, causing mortality and affecting their development (Cruz et al., 2017). Basil oil has shown potential in managing *S. frugiperda* when combined with synthetic insecticides, potentially reducing the amount of synthetic pesticide needed

(Malapermal et al., 2015). Therefore, the present research work will be performed to evaluate toxicity of *O. basilicum* against the larvae of *S. frugiperda* under laboratory conditions. Objectives of the research; To assess the lethal and sublethal effects of sweet basil against the larvae of *S. frugiperda* and to optimize the concentration dose of *O. basilicum* against the larval stages of *S. frugiperda.*

## MATERIALS AND METHODS

### Study area

A laboratory experiment was performed at the Integrated Pest Management Laboratory, Department of Plant Protection, Faculty of Crop Protection, Sindh Agriculture University Tando Jam to evaluate the insecticidal properties of plant extracts of *Ocimum basilicum* (Niazboo) against the maize fall armyworm.

### Experimental design

The laboratory experiment was designed and performed, followed a Complete Randomized Design (CRD) with three replications.

### Collection of *Spodoptera frugiperda* larvae

To meet the objective of studying insects at the larval stage, collected the 3rd and 4th larval instars of the fall armyworm from the maize field and brought them to the laboratory for diagnosis, validation of larval stages, and further experiments.

### Preparation of *Ocimum basilicum* extract

One kg fresh leaves of *O. basilicum* (Naizboo) was harvested and stored for additional processing in the laboratory. The plant leaves were chopped into little pieces. The leaves were then cooked for an hour in the lab on a hot plate, and liquid solution was extracted through muslin cloth and keeps it in glass containers for spray at target places.

### Treatments detail

The liquid extracts of *O. basilicum was* used at lowest to highest doses.

T1=10 ml/1 liter water, T2=25ml/1 liter water, T3= 75 ml/1 liter water, T4 = 100 ml/ 1 liter water. T5 = Control only 1liter tape water.

### Lethal effects of *Ocimum basilicum against Spodoptera frugiperda*

*S. frugiperda* larvae in their third and fourth instars were used for the bioassay, and the test larvae were applied topically. Fifty (50) larvae with three replications were utilized in each treatment. The necessary number of fall armyworm larvae (50/replication) of the same stage (third and fourth larval instar) was placed in 12 x 12 x 12-inch plastic cages one day prior to application. The pretreatment larval population was measured 24 hours prior to treatment, and the post treatment population was measured 1, 3, 5, and 7 days following spray. Pieces of soft stem and maize leaf will be put inside the cages for the larvae to eat. Additionally, Abbots (1925) was used to determine the mortality % based on the live and dead larvae.

Abbot's Formula= $1 - \frac{T}{C} \times 100$

### Population of treatment

The percentage of insects killed in the treated group.

### Population of control

The percentage of insects that died in the untreated control group.

### Sub-lethal effects of *Ocimum basilicum against Spodoptera frugiperda*

Sub lethal effect refers to the physiological and behavioral impacts on the larvae that survive initial exposure.

### Dose optimization

The study was optimizing the concentration dose to identify levels that affect growth without immediate death.

### Development monitoring

Survival and development of the third and fourth instar larvae was monitored throughout the seven-day post-treatment period.

### Feeding behavior

Larvae were provided with maize leaves to observe how the extract (containing terpenoids like linalool) affect their feeding and ability to consume host tissue.

### Statistical analysis

The mortality data were analyzed using Abbot's formula. The mean mortality data for each treatment was tested using analysis of variance in the treatment means (ANOVA) at the 95% confidence level, followed by the Turkey HSD test by using *Statistix 8.1* software.

## RESULTS

### Mortality percentage of 3rd instar*S. frugiperda* larvae

The larvicidal potential of sweet basil extract against third instar *S. frugiperda* larvae was evaluated at four different doses (10 ml, 25 ml, 75 ml, and 100 ml) over a period of seven days. Larval mortality percentage was recorded after one, three, five and seven days after treatment, and the values were expressed as mean ± standard error (S.E). No mortality was observed in the control group throughout the experimental period, confirming that larval death was solely due to the application of sweet basil extract. At the lowest concentration (10 ml), larval mortality showed a gradual increase with time. Mortality was recorded as 25.15 ± 3.25% on the 1st day, which slightly increased to 27.63 ± 2.52% on the 3rd day, followed by 32.65 ± 3.58% on the 5th day and 35.52 ± 6.58% on the 7th day. This indicates a relatively weak larvicidal effect at lower dose. At a dose of 25 ml, a moderate larvicidal effect was observed. Mortality

increased from 38.99 ± 4.88% on the 1st day to 42.52 ± 5.58% on the 3rd day and reached a maximum of 56.63 ± 5.36% on the 5th day. However, a slight reduction in mortality (52.36 ± 6.36%) was recorded on the 7th day, which may be attributed to experimental variation. A significant increase in larval mortality was observed at higher concentrations. At 75 ml, mortality was already high on the 1st day (59.36 ± 12.36%) and continued to increase with exposure time, reaching 68.99 ± 18.36% on the 3rd day, 72.36 ± 12.58% on the 5th day, and 83.55 ± 12.36% on the 7th day. This indicates a high larvicidal activity of the sweet basil extract at 75 ml dose. The larvicidal activity was the most pronounced in the highest concentration (100 ml). Mortality started at 70.25 ± 14.25% on the 1st day and increased to 82.65 ± 19.52% on the 3rd day, 89.20 ± 6.36% on the 5th day, and reached the highest recorded value of 91.63 ± 16.69% on the 7th day. This implies that the efficacy of sweet basil extract increases in a linear proportion to its dose and duration of exposure. Generally, the findings reveal a time-dependent dose-dependent response in larval mortality. An increase in concentrations and exposure time led to a much higher death rate (Table 1).

Table 1: Mortality percentage of 3rd instar *Spodoptera frugiperda* larvae due to the application of *Ocimum basilicum* extracts after different intervals.

| Extract | Observation duration (days) | | | | |
|---|---|---|---|---|---|
| | Dose | One | Three | Five | Seven |
| Sweet basil extract | 10ml | 25.15 ± 3.25 D | 27.63 ± 2.52 C | 32.65 ± 3.58 B | 35.52 ± 6.58 A |
| | 25ml | 38.99 ± 4.88 C | 42.52 ± 5.58 B | 56.63 ± 5.36 B | 52.36 ± 6.36 A |
| | 75ml | 59.36 ± 12.36 B | 68.99 ± 18.36 B | 72.36 ± 12.58 B | 83.55 ± 12.36 A |
| | 100ml | 70.25 ± 14.25 A | 82.65 ± 19.52 A | 89.20 ± 6.36 A | 91.63 ± 16.69 A |
| | Control | 0.00 E | 0.00 E | 0.00 E | 0.00 E |

**Mortality percentage of 4th instar *Spodoptera frugiperda* larvae**

The larvicidal potential of sweet basil extract was evaluated against fourth instar *S. frugiperda* larvae at four different dose (10 ml, 25 ml, 75 ml, and 100 ml) over a period of seven days. Larval mortality percentage was recorded on the one, three, five and seven day after treatment, and the values were expressed as mean ± standard error (S.E). No mortality was observed in the control group throughout the experimental period, confirming that larval death was solely due to the application of sweet basil extract. At the lowest concentration (10 ml), larval mortality showed a gradual increase with time. Mortality was recorded as 25.15 ± 3.25% on the 1st day, which slightly increased to 27.63 ± 2.52% on the 3rd day, followed by 32.65 ± 3.58% on the 5th day and 35.52 ± 6.58% on the 7th day. This indicates a relatively weak larvicidal effect at lower dose. At a dose of 25 ml, a moderate larvicidal effect was observed. Mortality increased from 38.99 ± 4.88% on the 1st day to 42.52 ± 5.58% on the 3rd day and reached a maximum of 56.63 ± 5.36% on the 5th day.

However, a slight reduction in mortality (52.36 ± 6.36%) was recorded on the 7th day, which may be attributed to experimental variation. A significant increase in larval mortality was observed at higher dose. At 75 ml, mortality was already high on the 1st day (59.36 ± 12.36%) and continued to increase with exposure time, reaching 68.99 ± 18.36% on the 3rd day, 72.36 ± 12.58% on the 5th day, and 83.55 ± 12.36% on the 7th day. This shows that the sweet basil extract has a great larvicidal effect at this dose. The larvicidal activity was most effective in the highest dose (100 ml). Mortality started at 70.25 ± 14.25% on the 1st day and increased to 82.65 ± 19.52% on the 3rd day, 89.20 ± 6.36% on the 5th day, and reached the highest recorded value of 91.63 ± 16.69% on the 7th day. This shows that the efficacy of sweet basil extract grows significantly as the concentration and time of exposure. In general, the findings indicate that there is a time-dependent and dose-dependent reaction in larval mortality. The level of dose and duration of exposure led to very high mortality rates. These results indicate that sweet basil extract has great larvicidal activity and can be used to provide a potential environmentally friendly alternative larval control outcome is as follows (Table 2).

Table 2: Mortality percentage of 4th instar *Spodoptera frugiperda* larvae due to the application of *Ocimum basilicum* extracts after different intervals.

| Extract | Dose | Observation duration (days) | | | |
|---|---|---|---|---|---|
| | | One | Three | Five | Seven |
| Sweet basil | 10ml | 24.15 ± 2.33 D | 26.63 ± 3.40 D | 33.77 ± 4.90 C | 37.13 ± 5.40 C |

| | | | | | |
|---|---|---|---|---|---|
| extract | 25ml | 40.00 ± 5.01 C | 43.44 ± 6.01 C | 50.13 ± 4.80 B | 54.77 ± 8.66 B |
| | 75ml | 60.22 ± 7.20 B | 69.00 ± 10.11 B | 73.00 ± 9.19 B | 81.00 ± 9.55 A |
| | 100ml | 71.15 ± 11.65 A | 80.77 ± 11.36 A | 88.10 ± 5.30 A | 90.00 ± 13.57 A |
| | Control | 0.00 E | 0.00 E | 0.00 E | 0.00 E |

**Larval duration (days)**

Figure 1 illustrates the effect of different concentrations of *O. basilicum* on the larval duration of *S. frugiperda*. The findings show that the development of the larvae was greatly elongated in all the treatment groups as compared to the control. The maximum larval period was observed to be at the highest dose (100 ml) with 19 + 2.36 days of the 3rd instar and 18.23 + 1.89 days for the 4th instar. This was followed by 75 ml (18 ± 1.50 days), 25 ml (16.24 ± 1.44 days), and 10 ml (17 ± 1.23 days), showing an overall trend of delayed development with increasing dose. Conversely, the control group had the lowest larval period (13 ± 2.36 days) which indicates normal development without any intervention. Statistical analysis showed that there were significant differences (P <0.001) between treatments. All tested doses of sweet basil extract affected larval duration; however, the effect was more pronounced in the 3rd instar compared to the 4th instar, indicating greater sensitivity of earlier larval stages to the bioactive compounds present in *O. basilicum.*

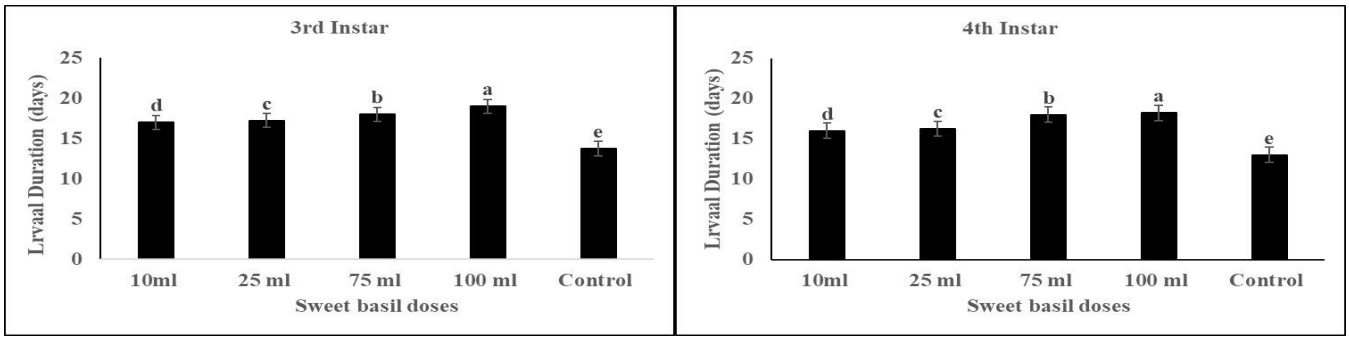



Figure 1: Effect of different sweet basil concentrations on the larval duration (days) of fall army worm.

**Larval weight (mg)**

The effect of different concentrations of *O. basilicum* on the larval weight of *S. frugiperda* is presented in Figure 2. The results clearly indicate that larval weight decreased significantly with increasing doses of sweet basil extract, as compared to the untreated control. For the 3rd instar larvae, the highest mean weight was recorded in the control group (520 ± 22 mg), reflecting normal growth conditions. Among the treated groups, the highest weight was observed at 10 ml dose (350 ± 10 mg), followed by 25 ml (280 ± 12 mg), and 75 ml (250 ± 20 mg), whereas the lowest weight at 100 ml (230 ± 11 mg). The same tendency was found in the 4th instar larvae. The highest mean weight was observed in the control group (600 ± 42 mg) with a gradual decrease with the dose: 300 ± 8 mg at 10 ml, 270 ± 9 mg at 25 ml, 240 ± 12 mg at 75 ml and the lowest weight (220 ± 22 mg) at 100 ml.

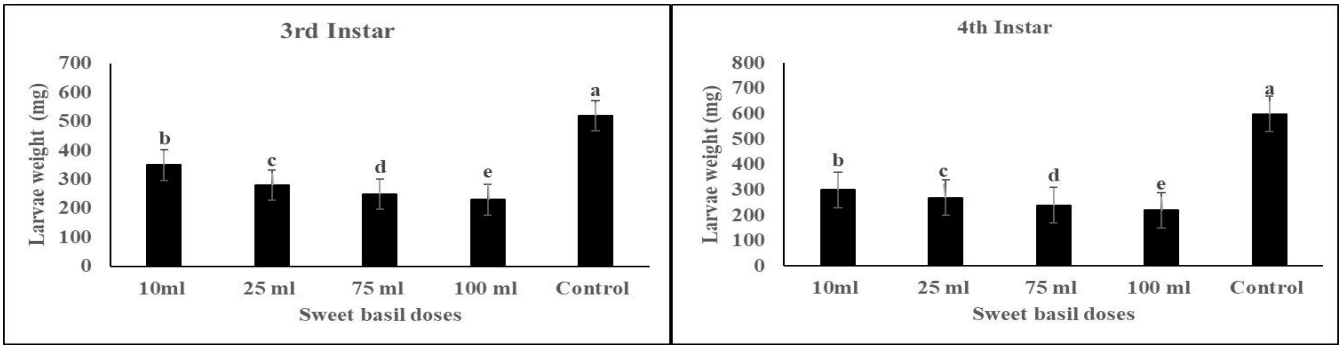



Figure 2: Effect of different sweet basil concentrations on the larval weight (mg) of fall army worm.

In general, a dose-dependent decrease in larval weight was evident in both instar stages. The values of the standard error are relatively low which means that the measurements were consistent among replicates. The decreased weight of

the larvae indicates that *O. basilicum* extract has a negative impact on larval development, probably because of the antifeedant effects and distortion of nutrient absorption and metabolism.

**Pupal duration (days)**

The influence of different doses of *O. basilicum* on the pupal duration of *S. frugiperda* is presented in figure 3. The results indicate that pupal duration increased in all treated groups compared to the control, demonstrating a clear sub-lethal effect of sweet basil extract on insect development. For the 3rd instar-derived pupae, the shortest duration was recorded in the control (5.00 ± 1.00 days). In contrast, pupal duration increased progressively with increasing doses of *O. basilicum*, reaching 7.00 ± 1.00 days at 10 ml, 9.50 ± 0.99 days at 25 ml, 10.00 ± 1.00 days at 75 ml, and the highest duration of 10.20 ± 1.00 days at 100 ml. A similar pattern was observed for the 4th instar-derived pupae. The control group showed the minimum pupal duration (4.76 ± 1.23 days), whereas treated groups exhibited prolonged durations: 8.00 ± 2.00 days at 10 ml, 9.00 ± 1.40 days at 25 ml, 9.65 ± 1.00 days at 75 ml, and 9.85 ± 1.00 days at 100 ml. Overall, the findings demonstrate a dose-dependent increase in pupal duration with increasing doses of sweet basil extract. The relatively low standard error values indicate consistency among replicates. This prolongation of the pupal stage may be attributed to physiological stress, metabolic disruption, or delayed development caused by bioactive compounds present in *O. basilicum*.

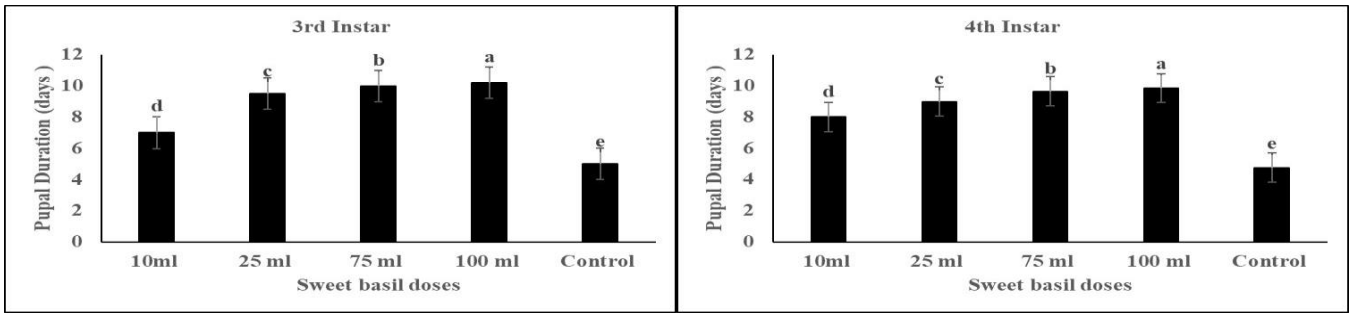



Figure 3: Effect of different sweet basil concentrations on the pupal duration (days) of fall army worm.

**Pupal weight (mg)**

The effect of different doses of *O. basilicum* on the pupal weight of *S. frugiperda* is presented in figure 4. The results revealed a noticeable reduction in pupal weight in all treated groups compared to the control, indicating a strong inhibitory effect of sweet basil extract on insect growth and development. For pupae derived from the 3rd instar larvae, the highest mean weight was observed in the control (300 ± 23 mg). In contrast, treated groups showed reduced weights, with 190 ± 10 mg at 10 ml, 185 ± 8 mg at 25 ml, 180 ± 12 mg at 75 ml, and the lowest weight (170 ± 10 mg) at 100 ml. A similar trend was observed in pupae originating from the 4th instar larvae. The control group recorded the maximum mean weight (360 ± 33 mg), while the treated groups exhibited lower weights: 200 ± 14 mg at 10 ml, 210 ± 12 mg at 25 ml, 190 ± 13 mg at 75 ml, and 200 ± 10 mg at 100 ml. Overall, pupal weight decreased in response to increasing concentrations of *O. basilicum*, although slight variation was observed among treatments in the 4th instar group. The relatively low standard error values indicate consistency in the data. The reduction in pupal weight suggests that sweet basil extract adversely affects nutrient accumulation and metamorphic development, likely due to its antifeedant and physiological stress-inducing properties.

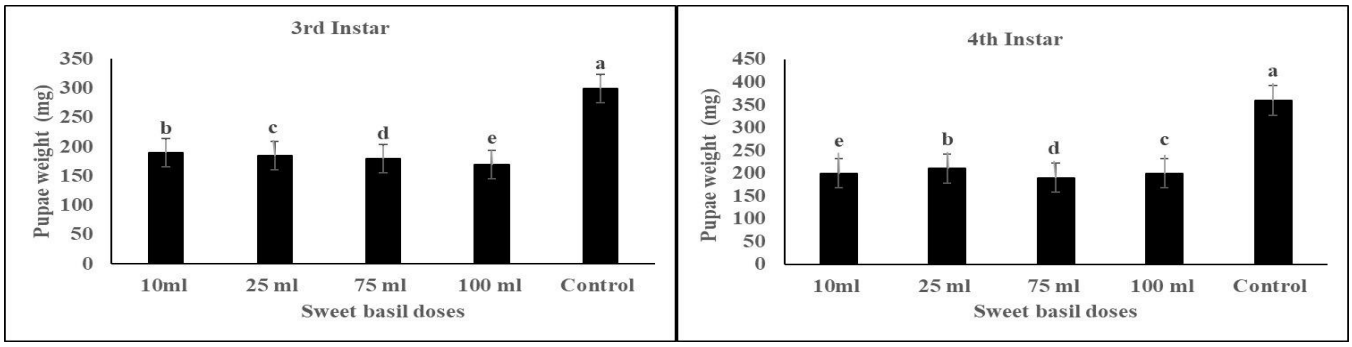



Figure 4: Effect of different sweet basil concentrations on the pupal (mg) of fall army worm.

## DISCUSSION

The current research shows that the sweet basil (*Ocimum basilicum*) extract has powerful lethal and sub-lethal impacts on *Spodoptera frugiperda* that has a significant impact on its survival, growth and development. The findings were clearly in the form of a dose and time dependent response, with high concentrations and extended exposure times incurring increased mortality in larvae, lengthening larval and pupal periods and pivotal larval and pupal weight. These effects suggest that the extract not only results in direct mortality but also interferes with normal physiological and metabolic functions resulting in slow development and biomass accumulation. Combined effects of this nature may eventually reduce the population growth through impacts on the survival and reproductive potential. The mortality in the control was also non-existent, which proves that the treatment was effective as well. Together, these results indicate the promise of sweet basil extract as a botanical insecticide with little environmental footprint and justifies its potential as part of the integrated pest management approaches to the sustainable management of fall armyworm.

The maximum larval period was observed in the highest concentration (100 ml) where it was 19.00 ± 2.36 days ($3^{rd}$ instar) and 18.23 ± 1.89 days ($4^{th}$ instar), compared to the control (13.00 ± 2.36 days). Similar was the case of pupal duration which rose to 10.20 ± 1.00 days at 100 ml as compared to the control at 5.00 ± 1.00 days. The results suggest that the extract does not hasten insect development, but rather slows it down, perhaps because of physiological stress, interference with endocrine functions or disruption of metabolic processes. Khalil and Rashed (2025) and Ibrahim et al. (2025) also reported such prolongation of the developmental stages and indicated that plant-based compounds can also change hormonal balance and slow down insect development. The weight of larval and pupal decreased significantly as the concentration of sweet basil extract increased. In the present study, larval weight declined from 520 ± 22 mg (control) to 230 ± 11 mg at 100 ml in the $3^{rd}$ instar, and from 600 ± 42 mg (control) to 220 ± 22 mg at 100 ml in the $4^{th}$ instar. Likewise, the weight of pupa dropped by 300 ± 23mg (control) to 170 ± 10mg at the maximum level of concentration in $3^{rd}$ instar-derived pupa and 360 ± 33 mg to approximately 200 mg in $4^{th}$ instar-derived pupa.

This decrease in biomass means that there is a high growth inhibitory effect, probably because of antifeedant effects and poor nutrient assimilation as a result of bioactive compounds found in *O. basilicum*. Similar larval and pupal weight losses have been documented by Phambala et al. (2020) and Ahmed et al. (2022) who have emphasized the application of botanical extracts in inhibiting insect growth and development. The toxicity of sweet basil extract was also observed to be lethal as indicated by the dose and time-dependent larval mortality. Mortality of $3^{rd}$ instar larvae was found in the current research to be at 100 ml high (91.63 ± 16.69) after seven days, whereas mortality of $4^{th}$ instar larvae was a little lower (90.00 ± 13.57) but similar. Mortality was relatively low (35.52 ± 6.58% in $3^{rd}$ instar and 37.13 ± 5.40% in $4^{th}$ instar) at lower concentrations (10 ml), which also confirmed the gradual increase in toxicity with increasing concentration and length of exposure. The control group, which had no mortality, is another confirmation of the sole death of larvae caused by the extract. This finding is consistent with the results of Vijitkul et al. (2025) and Kavitha and Shanthi (2024), who indicated that botanical extracts had high larvicidal effects on the lepidopteran pests.

Likewise, Mead (2018) established the efficacy of *O. basilicum* essential oil against Spodoptera species, which proves the efficacy of the insecticidal effect in the current study. In sum, the experiment affirms that sweet basil extract has both lethal and sub-lethal impacts on fall armyworm, such as extended developmental period, lower larval and pupal weight, and high larval death. The lengthening of life cycles and a decrease in biomass could have a negative effect on adult development, reproduction and population increase. These results are in agreement with the prior reports (Phambala et al., 2020; Sisay et al., 2019; El-Sappagh et al., 2022), which emphasized the potential of botanical extracts to inhibit feeding, growth, and survival of *S. frugiperda*. This study has shown that its dose- and exposure-dependent response is clear, which highlights the need to maximize the extract concentration in order to control pests. Thus, *O. basilicum* extract can be regarded as a prospective ecofriendly alternative to synthetic insecticides and can be included into the sustainable pest management plans to control fall armyworm.

## CONCLUSIONS

The present laboratory study demonstrated that *Ocimum basilicum* (sweet basil) leaf extract has significant insecticidal and growth regulatory effects against *Spodoptera frugiperda* under controlled conditions. The extract exhibited a clear dose-dependent and time-dependent increase in larval mortality across all tested concentrations (10, 25, 75, and 100 ml/L) and exposure periods. Among all treatments, the 100 ml/L dose was the most effective and

best-performing concentration, producing the highest mortality in both larval instars. It recorded 91.63% mortality in 3rd instar and 90.00% in 4th instar larvae after 7 days, showing a strong increase compared to lower doses. The 75 ml/L treatment ranked second, with high mortality values of 83.55% and 81.00%, followed by 25 ml/L, which showed moderate effectiveness. The lowest activity was observed at 10 ml/L, although mortality gradually increased with exposure time in all treatments. No mortality was recorded in the control, confirming that all effects were due to the plant extract. In addition to direct mortality, the extract produced strong sub-lethal effects on insect development. Larval duration was significantly prolonged (up to 19 ± 2.36 days compared to 13 ± 2.36 days in control), indicating delayed growth. A clear reduction in larval and pupal weights was also observed, particularly at higher doses (75–100 ml/L), suggesting impaired feeding efficiency and nutrient utilization. Similarly, pupal duration increased while pupal weight decreased, indicating disruption of normal metamorphosis and physiological processes. In conclusion, the 100 ml/L dose is the most effective treatment, followed by 75 ml/L, due to its highest mortality and strongest growth inhibition. Sweet basil extract therefore shows strong potential as an eco-friendly botanical insecticide for sustainable fall armyworm management within integrated pest management (IPM) programs.

## RECOMMENDATIONS

Based on the findings of the present study, the following recommendations are proposed:

1. *Ocimum basilicum* (sweet basil) leaf extract should be considered a promising botanical insecticide for the management of *Spodoptera frugiperda* in maize crops under eco-friendly pest control strategies.
2. The concentrations of 75–100 ml/L showed higher effectiveness and should be further optimized for practical field application and economic feasibility.
3. Field trials are strongly recommended to validate laboratory results under natural environmental conditions such as temperature variation, rainfall, and pest pressure.
4. Sweet basil extract should be incorporated into Integrated Pest Management (IPM) programs to reduce dependence on synthetic insecticides and delay resistance development in pest populations.
5. Further research is needed to isolate and identify the active bio-compounds responsible for insecticidal activity and to develop stable, standardized formulations for large-scale use.
6. Studies should also evaluate the impact on non-target organisms, including natural enemies and pollinators, to ensure environmental safety.
7. Awareness programs should be promoted among farmers regarding the use of plant-based pest control methods for sustainable and low-cost agriculture.

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