CHAPTER 2

2. REVIEW OF LITERATURE

The *Spodoptera frugiperda* Smith, 1797 (commonly known as fall armyworm or FAW) is an ecologically important agricultural pest of the world. It causes damage to several crops of ecological importance. The FAW was limited to the agricultural fields of the American continent before invading Africa in 2016 and Asia in 2018. The first reported case of *Spodoptera frugiperda* was on maize in Karnataka, India, and it was the first report from the continent of Asia.

Deshmukh and colleagues (2018) reported *Spodoptera frugiperda* for the first time in India on maize fields and later on other crops in Karnataka state at Agricultural University fields. The confirmation was done through molecular analysis. Male genitalia characters of FAW got matched with previous publications of *S. frugiperda* that confirmed species identity. Such characters play a prominent role in species identification and confirmation.

FAW has spread in many countries in Africa and Asia in recent times. Various agencies and agricultural systems caused timely detection in January 2019 in Yunnan province of China. It is neighbouring Myanmar. Dynamic tracking of FAW spreading to 13 regions within four months in southern provinces. The initial detections of the corn strain of *Spodoptera frugiperda* in China were confirmed using the molecular marker method- CO1 and Tpi genes by **Jing and friends (2019)**. The other three noctuid larvae- *S. exigua, S. litura*, and *Mythimna separata* with the resemblance in morphology, co-occur and cause similar damage in southern China cornfields.

The pest *S. frugiperda* has been creating a problem in Gujarat since its identification. **Sisodiya et al. (2018)** reported the first fall armyworm occurrence in Gujarat in the sweet corn fields. It was found in the Anand district's Anklav village in September 2018. The insect was confirmed and identified later through molecular and morphological identification. Before this, reports of fall armyworm invasion had already come from southern parts of India. Distinct morphological features are the basis of its primary identification.

A study on the status of FAW in Junagarh by **Naganna and colleagues (2021)**. Later **Damasia and team (2020)** found Fall armyworm occurrence in finger millet fields in Gujarat in Dangs district. Naganna did a study on the status of FAW in Junagadh, where the details of pest infestation within two years in India are discussed. The fall armyworm has invaded and affected many Indian states, including Karnataka, Andhra Pradesh, Maharashtra, Telangana, Gujarat, and Tamil Nadu. It prefers a warm climate and is known to cause infestation up to 35% in maize fields. The invasion in Gujarat came much later than in South Indian states. Although FAW is a major pest of maize, it is also a pest of many other crops including millet. Fall armyworm occurrence in finger millet fields were recorded for the first time in Gujarat in Dangs district by team of Damasia. Damage up to 46% was recorded in the fields of Hill Millet Research Station, Waghai. Larvae were confirmed to be FAW after characterization was done morphologically at Navsari Agricultural University.

Outside Gujarat, several cases of *S. frugiperda* were reported too. The first occurrences of the exotic pest fall armyworm in sugarcane were reported by **Srikanth and team (2018)** from the south Indian state of Tamil Nadu, in the sugarcane belts at Erode and Karur districts, Tamil Nadu. In both places, young crop variety Co 86032 was attacked with incidence levels between 1.85-30.86%. Symptoms of damage include leaves with skeletonization, irregular holes/windows on the lamina, and margin feeding. In severely affected plants, mature larva hides in the whorl in large quantities of fresh faecal pellets and patches of dry grass on older outer leaves. 9

Spodoptera frugiperda has been identified in Southern Rajasthan by **Babu and his team (2019)**. It was through morphological and DNA barcoding methods. The percentage damage was between 10 to 40% in different hybrids. FAW larvae were found during the vegetative stage of the crop (knee height stage). It continues up to the cob formation stage. Features include dark brown to grey colour larvae having an inverted 'Y' shape on the head with four dark-coloured black spots arranged in a square on the abdominal segment in the eighth segment and a trapezoidal pattern on the ninth abdominal segment.

Chormule and colleagues (2019) stated that although FAW is polyphagous, it has been majorly attacking maize, followed by sorghum. Certain qualities aid in such devastating nature of the FAW. Qualities like high dispersal ability, broad host range and high fecundity make this pest even more severe. In the Sangli district of Maharashtra, FAW was seen on sugarcane and other crops. From the phylogenetic tree, it was found that it belongs to the "C" corn strain. The corn/maize strain is the more severe strain causing danger for the agriculture sector in the country. Natural enemies like *Noumuraea rileyi* and *Campoletis chloridae* saw significantly less activity. The sugarcane fall armyworm belonged to the 'corn' strain. Several such cases kept coming, mainly in the maize-growing regions of the country.

Padhee & Prasanna (2019) reviewed the case of fall armyworm occurrence in India. The fall armyworm started its spread from Africa in 2016 while India in 2018 in Karnataka. Later in the year spread to various districts of Karnataka and neighbouring states like Tamil Nadu. Due to its severity, the National Bureau of Agricultural Insect Resources of ICAR has also raised pest alerts. The damage was as severe as over 70% prevalence in maize fields and also damaged other crops like sorghum and sugarcane. Its invasion in Gujarat started in 2018, and damage has been mainly observed in the maize fields.

Kumar et al., 2022 explained the current ways of control of FAW in India. Ever since the *Spodoptera frugiperda* invasion in India, the only effective way to control the pest has been by applying chemical insecticides. The Indian government has also approved a few insecticides against FAW. However, the susceptibility of the pest varies in different regions of India. It was found that, out of the five central corn-producing states taken, Bihar has the least while Karnataka has the most susceptible population. It is essential to know the susceptibility status of the species before applying insecticides for better results.

S. frugiperda has been attacking several crops of importance. **Montezano with his team (2018)** enlisted 353 host plants of *S. frugiperda* through a survey in Brazil. Fall armyworm is known to be a polyphagous pest. To reduce the risk of various crop failures, the knowledge of host crops is essential. As much as plants from 76 families, like Poaceae, Fabaceae, etc., are hosts to FAW. Around 82 new records were found from the study conducted. Various traits favour the considerable capacity of FAW. Qualities that aid in its devastating nature are high dispersal ability and broad host range.

In our field survey, we found the major infestation in maize crops, followed by other crops like sorghum and millet. With years of experience handling lepidopteran pests in the laboratory, we could observe the *frugiperda* species' hyperactive nature compared to others like *litura*. **Haenniger et al., 2020** saw that not much sexual communication difference was observed in the response between the two strains. They had similar pheromonal compositions. However, geographic variations between the American and African populations were observed with differences in sensitivity to pheromonal components. Different geographic regions may have different strains of the species present.

The status of any pest needs to be known before starting actual control. Such a review of pests' status has been done in the past. **Rao & team (2020)** reviewed the status of pink bollworms on *Bt* in India scenario. The reason behind such heavy destruction of *Bt* cotton by this pest in India is due to its resistance to Cry toxins in most Indian population which is multi-fold as well. Cultivation throughout the year is also an issue resulting in this problem. An effective IPM implementation can resolve the issue.

High loss by FAW causes a need for control measures. An evaluation was done by **team Harrison (2019)**. It is estimated that a loss above $US13 billion by FAW in Africa pushes the farmers to use more and more pesticides for prevention. Nevertheless, such usage can harm human health as well as the environment. Agroecological approaches can have more cost-effective ways of control. Several measures can be immediately adopted, like sustainable soil fertility management, intercropping with selected companion plants, and diversifying the farm environment.

The devastation caused by pests needs to be estimated. **De Groote and his team (2020)** estimated crop loss in the agricultural fields of Kenya region in Africa**)**. The survey was done in all the maize-producing areas of the region. The number of farmers affected by maize crop loss increased from 2016 to 2017. The percentage of maize loss, however, decreased from 2016 to 2017, which varied between high, low, and medium potential areas. The per cent loss also varies in various maize-producing areas in India.

All the mentioned issues by the agricultural pest call for a compelling management need. We must be assured that such management can provide good results. The relationship between yield and management should be looked upon. In studies done by **Tambo & friends (2020)**, it has been figured out that successful management of FAW can be done, which creates a massive improvement in the crop yield. Prevention and control methods used by farmers in Ghana and Zambia were observed. Knowledge of the pest with pesticide application and mechanical control like hand-picking plays a significant role in crop production enhancement. Better awareness can also lead to more methods of control. Such measures can be applied in our country for an integrated approach.

The life cycle of any organism needs to be known before conducting studies. The days of completion of a cycle of life are essential to have complete information on the pest. Maize is an important crop after wheat and contributes a lot to feed and food. The pest *S. frugiperda*, which attacks maize, has also been occurring in Indonesia since 2019. Studies by **Maharani et al., 2021** found that the life cycle of fall armyworm was completed in 32 days on maize and 37 days on rice. Significant differences in the life tables of the two types of caterpillars were seen, including the maize-fed caterpillars' greater lengths and higher survival rates than the rice-fed ones.

Knowing the complete life cycle of any pest is essential to find out the various control stages. The life history of FAW lab conditions was studied at UAHS, Shivamogga, Karnataka, by **Sharanabasappa, with others (2018)**. With a fecundity of 1064 eggs, gravid females were producing eggs. The duration of the egg, the whole larva, and the pupa was found to be 2-3, 14–19, and 9–12 days, respectively. Male and female life cycles were found to be 32–43 and 34–46 days, respectively, in length. The larvae consumed hosts such as sorghum, tomato, cabbage, and sugarcane but not rice, demonstrating their affinity for the Corn strain. In our study strain of FAW is also of corn type.

The recent invasion and heavy destruction by FAW in the agriculture fields of India have created the need for looking every possible way of its control. Many studies have been done on previously occurring agricultural pests in Gujarat, including lepidopteran pests like *Spodoptera litura and Plutella xylostella*. The initial study of FAW started in 2018 in Gujarat. After that, work on the new invasive species is going on at some places like Anand, Vadodara, Navsari, and Junagarh. The biotic and abiotic factors play a role in insect growth, development, and reproduction. Abiotic factors play a significant role in insect growth and development. **Patel et al., 2021** studied the correlation and regression of mango thrips with abiotic factors in the Kesar mango plantation region in South Gujarat. Amongst the various weather parameters, a significant positive correlation was seen in the case of sunshine with thrips. However, evaporation rate, evening relative humidity, and maximum temperature negatively correlate with thrips. The study suggests a significant effect of abiotic factors on insect incidences.

Our study considered the major biotic and abiotic factors- temperature, humidity, and diet for rearing FAW. There are various ways to control a pest, including chemical control, bio-control, etc. Chemical control of FAW through commercially available insecticides has also been studied in the fields. Insecticide evaluation against fall armyworms has been done in Gujarat. **Thumar et al., 2020** did a field experiment during the Kharif season at Sansoli, Anand, and Godhra. Insecticides Chlorantraniliprole, Emamectin benzoate, Spinetoram, and Thiodicard were effective against the pest. The results are reflected in the form of higher yield obtained with the help of mentioned pesticide application. Chlorantraniliprole and Emamectin benzoate is among the favourable insecticides against FAW and therefore were preferred to be checked by us for extensive lab testing and analysis.

Other lepidopteran pests have been tried to control with different pesticides too. In the Junagarh area of Gujarat, **Bhut and team (2022)** did field experiments on the efficacy of chemical insecticides against two of the major pests of castor- *Spodoptera litura* and *Achaea janata*. A significant positive result was observed in the treated ones over the untreated ones. The tiny pest larvae were observed in the ones treated with Chlorantraniliprole. Other than them, Spinosad and Emamectin benzoate were also influential.

Combination insecticides often provide effective control against insects. One such Fludora (combination of neonicotinoid and pyrethroid) was used against *Anopheles culcifacies*, a rural malarial vector in Gujarat, by **Kamaraju and team (2021)**. Three villages were used for the study, where insecticides were sprayed through hand compression sprays. Parameters like mortality and repellency were well achieved, proving Fludora to control the disease-causing insects effectively.

The control by insecticides on other pests was also checked. Insecticide efficacy was checked by **Devashrayee et al. in 2022** in Navsari, Gujarat, against Indian bean pod borers. In all of the insecticides tested, Emamectin benzoate 5SG came out to be the best with maximum pod yield and increase in a pod over control. It was effective against both *Helicoverpa armigera* and *Maruca vitrata.* Also, Indoxacarb 14.5 SC effectively controlled the pests after Emamectin benzoate.

New insecticides are suitable, but their risk needs to be evaluated. **Paramasivam and colleagues**, **2022** in Tamil Nadu, India, checked the Chlorantraniliprole risk assessment in chilli fields. This was done using gas chromatography-mass spectrometry. Results revealed no dietary risk quotient (R.Q. < 1) and low risk (R.Q. < 1) to earthworms and arthropods. As Chlorantraniliprole is an effective pesticide that is widely used in the present times, such evaluation is necessary. Emamectin effectively controls other lepidopteran pests.

Novel insecticides Spinosad and Emamectin benzoate were checked against *Helicoverpa armigera* on tomatoes in Varanasi, U.P., by the **team of Singh (2022)**. Outcomes showed that Spinosad 45 SC (75 g ai/ha) and Emamectin benzoate, either E.C. or WSG formulations application (15 g ai/ha), efficiently controlled tomato fruit borer. These compounds can be used in the pest management strategy to achieve the expected control.

Even though much work with chemical insecticides is done, a study with the technical grade Chlorantraniliprole and Emamectin benzoate in the Gujarat FAW population is novel, so we did this study. Here we also lab-reared insects and tested them for some generations as well.

Apart from spraying chemicals on the plant, various other methods to control pests have been studied previously. Insect damage is generally avoided after the plant is grown and insects are seen. However, protection can be done in the seed stage to avoid damage after the plant grows. **Dobariya & Sisodiya (2022)** at Anand, Gujarat, did an insecticide evaluation as seed treatment against fall armyworm. The plant selected for the study was fodder maize. Tested ones were Cyantraniliprole 19.8 + Thiamethoxam 19.8 FS @ 6 ml/kg of seed, Fipronil 5 S.C. @ 6ml/kg of seed, Fipronil 5 S.C. @ 8ml/kg of seed, Thiamethoxam 30 F.S. @ 6 ml/kg of seed and Imidacloprid 600 FS @ 6 ml/kg of seed. It was seed treatment of Cyantraniliprole 19.8 + Thiamethoxam 19.8 FS @ 6 ml/kg of seed, giving the highest yield and damage as low as 29.97%.

Lunagariya et al., 2020 did field experiments for poison baits evaluation against *Spodoptera frugiperda* in the Kharif season at three farms of Anand Agricultural University. Grain and fodder yield were the criteria for finding the best baits. Some of them, like rice bran 25 kg + jaggery 5 kg + Emamectin benzoate 5 SG 125 g/ha, were found to be suitable for control against FAW. These can be effective for controlling the pest.

Maize is a crucial cereal like wheat and rice and needs to be protected for food security. This was a significant reason for us to be taking up the studies as well. While insecticides are one possible solution for protection, several better options are also there, including biopesticides and natural enemies. Biopesticides were checked against fall armyworms by **Dhobi and colleagues (2020)** at Anand, Sansoli, and Godhra. From these, *N. rileyi* 1% W.P., then *B. thuringiensis* proved to be the ones giving the highest yield when treated in maize fields.

Nucleo Polyhedro Virus can become a significant part of integrated pest management for fall armyworms. **Raghunandan and team (2019)** studied NPV infecting FAW at Kanisha in Anand district, Gujarat. The study revealed the presence of various sizes of occlusion bodies under phase contrast microscopy. Also, pathogenicity studies confirmed the presence of NPV in FAW of that region. NPV helps FAW control and can be added to a strategic IPM plan.

Lepidopteran pest causes heavy damage in agricultural fields. Two such pests are fruit borers, *Helicoverpa armigera* and *Earias vittella*. Okra is an important crop destroyed by the mentioned pests. Screening of various okra cultivars and genotypes was done by **Subbireddy's team (2018)** for their resistance capacity. None of them was found considerably resistant to the all then ten screened. Also, a negative correlation was found between fruit damage with morphological characteristics.

Plant Growth Regulators and Silicon have a negative impact and can act as inhibitors of growth and development in FAW, as studied by **Nagaratna et al., 2022**. Experiments were conducted to check the effect of PGRs and Si against FAW. The caterpillars were fed a diet treated with Foliar Silicic Acid (FSA), Gibberellic acid (GA3), and Jasmonic acid (J.A.). Certain combinations significantly reduced the weight, survival, and other biological parameters of fall armyworm, like that of FSA at 2 ml L^{-1} and GA3 0.5 mg $plant^{-1}$. These can also act as a method of controlling the pest.

Lad and Pawar (2022) evaluated insecticide's effect against FAW in Sorghum fields. The Jowar or Sorghum is an important crop, and *Spodoptera frugiperda* is a pest on it. Emamectin benzoate came out to be effective against the pest in Jowar fields. Other than that, Thiamethoxam + Lambda-cyhalothrin, Indoxacarb, Spinosad, and Profenophos were also influential. This supports our selection of the insecticide Emamectin benzoate against fall armyworms.

Bio-control agents are other organisms capable of killing pests. The biological methods of controlling pests are also essential to the IPM program. **Aarthi, Tamboli, and More (2022)** at the College of Agriculture, Pune, checked the bioefficacy of bio-control agents in the laboratory against different stages of fall armyworm. Findings against FAW eggs showed that Azadirachtin and *S. carpocapsae* were superior to *M. anisopliae* and *N. rileyi*, *B. bassiana*, and Bt in the second instar larval stage, and that Azardiractin and S. carpocapsae were superior to *M. anisopliae* and *N. rileyi*, *B. bassiana*, and *Bt* in the pupal stage. This demonstrates how effectiveness changes depending on one's stage of life.

In Bihar and Uttar Pradesh, **Verma and team (2016)** suggested eco-friendly management of fall armyworms. This included monitoring: scouting, cultural control, mechanical control, biocontrol, and chemical control. The chemical treatments are also given as per the stage of the plant, and the extent of damage found. Such an approach can help in reducing pest invasion and damage.

At the Maize research station, Godhra, AAU, field experiments were conducted to check the resistance of different maize hybrid varieties against *Spodoptera frugiperda.* **Varma with colleagues (2022)** screened various maize cultivators during the Kharif of 2020. In Godhra and Anand, Gujarat. Here, the highest resistance with the lowest damage was observed in hybrid maize cultivars- GAYMH 3, GAYMH 1, and GAWMH 2, and hybrid varieties- NARMADA MOTI and G.M. 6. In contrast, the lowest resistance with the most remarkable leaf damage was observed in sweet corn hybrid GSCH 0918. Sweet corn was found to be susceptible under natural conditions.

The molecular mechanisms can be known by checking resistant populations. There are two strains of FAW known, and their behaviour needs to be known. Several different compounds are tested to create control. The economy of Brazil is highly supported by agriculture. However, the continuous food present and the favourable climate invite the pest population to like that of the fall armyworm. **Fernandes and team (2018)** checked the efficacy of chemical insecticide control for the isolated and combined compounds. Chlorfenapyr + zeta-cypermethrin treatment had 100% efficacy in larval mortality. Insecticide application forms a quick and effective way of control against the pest.

We checked the effectiveness of Chlorantraniliprole and Emamectin benzoate against fall armyworm after rearing it inside the lab for some generations. **Boaventura et al., 2020** tried to identify the mechanism at the molecular level by using two resistant populations. There were three mutated ABCC2 sites of the Cry1F-resistant gene. Also, G.Y. deletion was found, which can be a significant factor in resistance. Deletions and mutation form an essential basis of resistance development.

Kaduskar and team (2022) used CRISPR/Cas9 editing to generate knockdown resistance mutations in isogenic laboratory Drosophila strains. Further, applying a CRISPR-based allelic drive replaces a susceptible wild-type with a resistant kdr mutation. Such study can help in harmful reversing resistant populations, the susceptible ones.

Resistance varies in different regions. Resistance monitoring was done by **Wang with others (2022)** in Beijing from sixteen geographical populations of the country between 2019 to 2021. Results revealed no resistance to Chlorantraniliprole, R.R. was found to be 0.32–2.32, and mutation frequency RyR as low as 0.14%. Emamectin benzoate is amongst some insecticides against which FAW was observed to be susceptible.

The role of detox enzymes is well known.

Metabolic detoxification plays a vital role in providing resistance to insects. The GSTs or Glutathione S-transferases by conjugation are known to cause resistance. In Henan, China, **Li et al., 2022** tried to find the function of GSTs in the delta group as it is unknown. One of them, SlGSTd1, shows a change in gene expression in pyrethroid resistance. Metabolic and peroxidase levels indicate that SlGSTD1 is involved in the Cyhalothrin resistance of *S. litura* by detoxication and antioxidant capacity.

Cytochrome P450 monooxygenases (CypP450s) play significant functions in insect physiology. They are also known to play an essential role in xenobiotic detoxification, which can be natural or synthetic. The cytochromes are essential genes that resist the insects against various chemical insecticides. However, **Nauen and colleagues (2022)** suggested that only a subgroup of P450 genes is linked with insecticide resistance. Complete knowledge of the P450s can help in counteracting the resistance problem.

The role of detoxification enzymes is prominent in resistance. One such group of enzymes is esterase. A study was done by **Parmar & Patel, 2018** in Gujarat on a lepidopteran pest, *Helicoverpa armigera,* a chief pest of the pigeon pea. The activity of esterase was checked for some locations in middle Gujarat. It was found to be highest in the Vadodara population, followed by the Ahmedabad population. Godhra and Anand showed moderate esterase activity as compared to the susceptible ones.

The midgut plays a role in causing resistance as the detoxification genes play an essential role there. In *Helicoverpa armigera*, the herbicides Butachlor and Haloxyfop-methyl cause resistance to the insecticide Methomyl and the fungal toxin Aflatoxin B1. **Sun and team (2019)** found that it happened due to an increase in P450 monooxygenase activity, primarily in the fat body and midgut.

Wei et al., 2019 stated that by studying its resistance mechanisms and invasion pathways, we could better understand the movement of resistance genes and invasion pathways. The destructive and invasive oriental fruit fly, *Bactrocera dorsalis*, is a polyphagous insect pest. For a better knowledge of the resistance gene flow pattern and invasion routes, it is crucial to understand this fly's resistance mechanisms and invasion pathways.

The insecticide Chlorantraniliprole is known to be used against the Colorado potato beetle. The Colorado potato beetle, *Leptinotarsa decemlineata*, was treated by **Dumas and friends (2019)** with the insecticide Chlorantraniliprole, which indicated the presence of a few HSPs (heat shock proteins), whose deletion led to mortality and verified HSPs role in resistance.

The GSTs or Glutathione transferases are a family of enzymes ubiquitously found in aerobic organisms. **Enayati et al., 2005** stated GST's significant role in detoxifying both endogenous and xenobiotic compounds. They are also involved in the biosynthesis of hormones, protection against oxidative stress, and intracellular transport **(Figure 2.1)**.

Li et al., 2019 discovered the cause for *Spodoptera litua's* resistance to tomatine in tomatoes was discovered through RNA sequence analysis of the animal's fat body and midgut, which implicated DEGs (differentially expressed genes) such as cytochrome P450 **(Figure 2.2)**.

Earlier other pests from the same family have been known to have developed resistance to insecticides. In Pakistan, **Ahmad and colleagues (2007)** tested field populations of *Spodoptera litura*, which were found resistant to conventional chemistries like Methomyl, Thiodicarb, Endosulfan, Chlorpyrifos, Profenofos, Phoxim, Quinalphos, Bifenthrin, Cyfluthrin using a leaf-dip bioassay method.

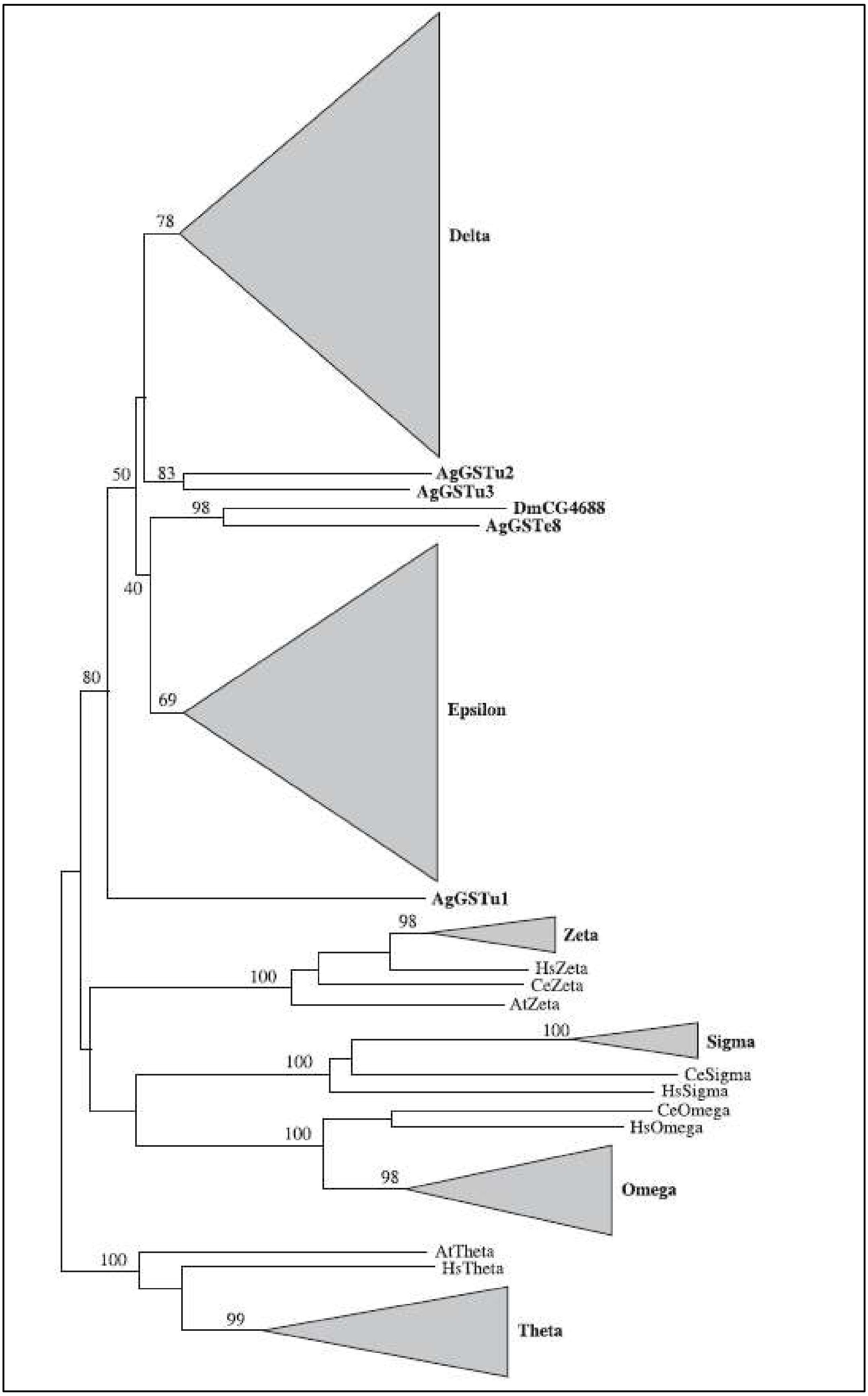

Figure 2.1: Tree depicting the relationship between the GST classes present in insects

(Source: Enayati et al., 2005)

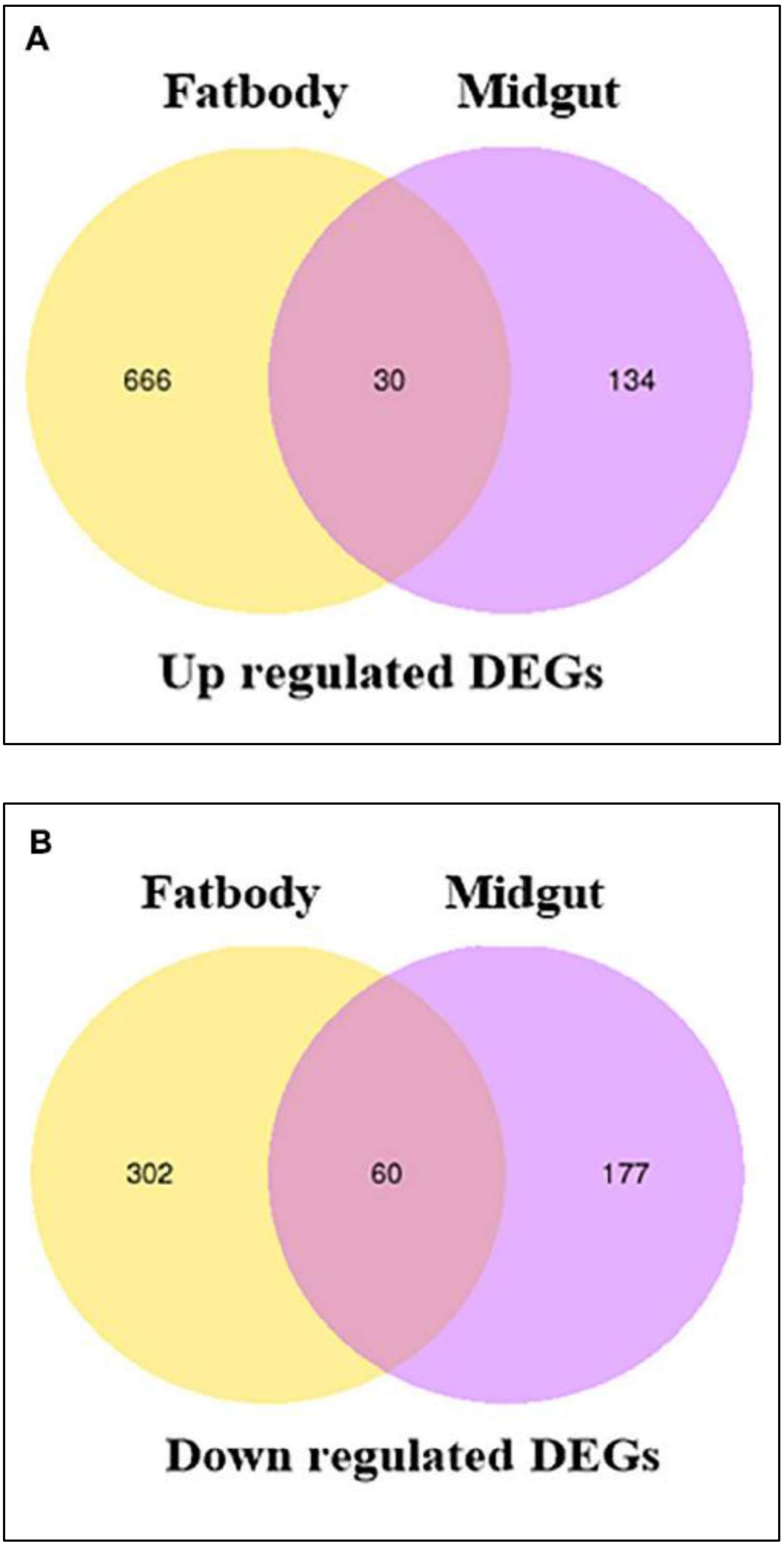

Figure 2.2: Venn diagram depicting the fat bodies and midguts differentially expressed genes in the of *S. litura* against treatment with tomatine **(Source: Li et al., 2019)**

Reports of Emamectin benzoate resistance by **Khan et al., 2016** have come in Pakistan on house flies, *Musca domestica* L. The resistance ratio (R.R.) increased many times from 35.15 to 149.26-fold in the field strain and showed rapid development of resistance to Emamectin.

The development of resistance against insecticide is the most challenging part of fall armyworm management. A reliable insecticide that delays resistance development and provides reasonable control is helpful in this pest management. Low risk of resistance evolution of *S. frugiperda* to Chlorfenapyr was found by **Kanno and team (2019)** through studies conducted with field populations in Brazil.

Our research identified numerous genes that confer pesticide resistance to the fall armyworm. As little research has been conducted on the pest, a comprehensive study from infestation to rearing, insecticide control, and resistance development is required for a better understanding. Additionally, the general new-generation insecticides and their long-term effects must be thoroughly evaluated. It was vital to examine in depth the numerous features of fall armyworms and associated insects for their existence, related pesticides, and resistance, which have been the subject of much research.

A thorough literature review has been conducted regarding the incidence and treatment of the pest. Although an incredible amount of effort has been made in insect pest management and associated challenges, more must be discovered to prevent the considerable damage they inflict. In addition, there are gaps in the process of conducting integrated research from field surveys through laboratory rearing. Additional pesticide testing and resistance research are required. Consequently, an attempt has been made to address FAW field infestation, laboratory rearing, feeding choice, pesticide efficiency against the pest, generation studies, resistance development, and the molecular basis of resistance.