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RESEARCH ARTICLE

Susceptibility of House flies (*Musca domestica* L.) Populations to Deltamethrin and Thiamethoxam

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ABSTRACT

The housefly, Musca domestica L. (Diptera: Muscidae) is cosmopolitan in nature and acts as carrier of various disease-causing pathogens in human and livestock. They are found in unsanitary conditions and badly maintained livestock farms. Conventional chemical insecticides are the sole reliance of farmers to combat this pest. They serve as carriers for numerous harmful agents that cause lethal diseases in both humans and livestock. The purpose of this study was to determine the susceptibility of housefly populations to deltamethrin and thiamethoxam in various livestock farms of Punjab, Pakistan. Susceptibility of four house fly population was evaluated against various concentrations of deltamethrin and thiamethoxam. The experiment was conducted on F1 of tested population, while lab strain acted as control treatment. Experimental conditions were maintained at 25±2 °C, 60±5% relative humidity (RH) and a 12:12 (D: L) hours photoperiod. Among the tested populations, Rahim Yar Khan population was highly susceptible to both insecticides followed by Bahawalpur, Lodhran and Multan as compared to the control. Mortality of adult house flies increased as the dose rate of insecticides increased for both pesticides. Deltamethrin was more effective than thiamethoxam against all tested populations. The study revealed that the use of deltamethrin is more effective, as compared to thiamethoxam, to control houseflies in livestock farms. Hence, it can be recommended for effective control of houseflies for sustainable animal production.

Key words: Housefly Susceptibility, Insecticide Efficacy, Livestock Disease Control, Deltamethrin vs Thiamethoxam, Sustainable Pest Management.

INTRODUCTION

Synanthropic pest, *Musca domestica* Linnaeus (Diptera: Muscidae), the housefly is found all over the world (Mukhtar *et al.*, 2021). This insect pest is prevalent in both urban and rural environments where people gather for employment and sustenance (Cetin *et al*., 2009). They found suitable feeding and breeding environments in unsanitary conditions and badly maintained dairy or cattle facilities, which leads to disease transmission (Khan *et al*., 2012). Before feeding, they secrete digestive juices, enzymes, and saliva on food before sucking it with its proboscis to liquefy it because they may eat from unsanitary sources, germs may adhere to their mouths and other body parts, and when these flies land on human food, they spread disease-causing agents (Zahoor *et al.*, 2020). In wet conditions, females exhibit a preference for depositing their eggs within organic residue. This inclination contributes to their abundance in locations like poultry farms, dairy cattle barns, livestock and horse enclosures, and other settings that facilitate their life cycle progression (Suwannayod *et al*., 2019).

Under ideal conditions, when housefly feeds and stays on unsanitary sites like rotting debris, human and animal waste they transmit a variety of lethal disease-causing agents to human and livestock (Khalid, 2022). The common diseases transmitted by *Musca* species, including houseflies, usually involve enteric infections, and skin infections (Cetin *et al.*, 2009). In poultry, they spread over 100 pathogens including protozoan, bacterial, helminthic, and viral agents (Abbas *et al.*, 2014).

Musca domestica is managed using a variety of ways, but the most common are chemical insecticides such as pyrethroids, carbamates, organophosphates,

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organochlorines and neonicotinoid (Khalid et al., 2021). Pyrethroids function by impeding the closure of sodium channel voltage gates situated within the axon membrane, as described by Scott et al. (2009). Improper application of these insecticides has resulted in the development of resistance among houseflies. The evolution of resistance in houseflies has been observed all around the world. The insecticides commonly employed to manage ectoparasites on animals encompass pyrethroids and neonicotinoids (Levchenko *et al*., 2019). Prior, studies reported on the development of pyrethroid and neonicotinoid resistant housefly populations on cattle and poultry farms worldwide (Abbas *et al*., 2015).

There are numerous scientific publications available on *M. domestica* resistance to carbamates, organophosphates, pyrethroids, and newly developed chemical insecticides. (Abbas *et al*., 2015b). The susceptibility of the *M. domestica* population to insecticides must be monitored in addition to applying insecticides effectively. Early detection of insect pest resistance to chemical pesticides, as well as the selection of a more effective management approach, can significantly reduce operational, financial, and environmental losses (Sharififard and Safdari, 2013).

Neonicotinoids are a relatively recent class of insecticides that are chemically related to nicotine and have been applied to control a variety of agricultural and public health pests for more than 20 years (Jeschke and Nauen, 2008; Zafar *et al*., 2022). They show a great biological efficacy against broad spectrum of insect pests including Diptera, Coleoptera, Thysanoptera, Hemiptera and Lepidoptera orders (Tomizawa, 2005). Many chemicals in the neonicotinoid family are commercially available, including thiamethoxam, acetamiprid, clothianidin, dinotefuran and imidacloprid (BABAR et al., 2022). Thiamethoxam is a second-generation nitro-substituted neonicotinoid pesticide. It is one of the most commonly used pesticides against the housefly (Fotedar, 2001). Thiamethoxam is a spray or paint-on insecticide that can be used to control houseflies in livestock facilities or rubbish containers. There have been a few instances of resistance around the world (Kristensen and Jespersen 2008; Khan *et al*., 2015).

Pyrethroids were developed to replace organophosphates and chlorinated insecticides due to their persistent nature. Pyrethroids, especially deltamethrin, are generally thought to be safe. However, there are few evidence on deltamethrin's harmful effects. Deltamethrin formulations are also commercially available for use in homes to keep biting mosquitoes, houseflies and other arthropod pests away (Khan *et al*., 2019). Deltamethrin has a fast-acting damaging effect on feeding insects, which raises the possibility that it could be used to inhibit the vectors of "non-persistent" viruses (viruses that can be transmitted by the vector within minutes of commencing to feed on the plant). Deltamethrin's mode of action is assumed to be primarily central, or at least originates in the brain's higher nerve centers (Bhanu *et al*., 2011). When poisoning lasts more than a few hours, severe damage to the nervous system appears to be the cause of insect death (Bhanu *et al*., 2011; Timothy, 2012). Cuticular penetration or oral uptake cause deltamethrin toxicity. Deltamethrin is the most powerful synthetic pyrethroid, with a very broad spectrum of control. (Bhanu *et al*., 2011; Anand *et al*., 20 06).

Integration of insecticides (with various modes of action) is more effective in resistance management systems than mosaics or rotational pesticide application because, if each pesticide in the mixture has its own resistance mechanism, the chances of both pesticides developing resistance at the same time are low (Khan *et al*., 2013; Zafar *et al*., 2020).

Numerous investigations have explored combined toxic effects, particularly the interactions between pyrethroids and other substances, on various dipteran insect pests across the globe (Zafar *et al*., 2020). However, as far as the authors are aware, such inquiries are infrequent in the context of housefly research, especially within Pakistan (Khan *et al*., 2013).

In order to achieve successful management of pest populations, including the housefly, it is essential to conduct monitoring to assess the susceptibility of field populations to the insecticides in use. The susceptibility of housefly populations from four different populations in Punjab, Pakistan, to neonicotinoid (thiamethoxam), pyrethroid (deltamethrin) pesticides and their combination (deltamethrin + thiamethoxam) under laboratory conditions was the major aim of this study. In this approach, the current work is expected to make a substantial contribution to the difficult challenge of developing effective and successful pesticide resistance management strategies for field populations.

MATERIALS AND METHODS

Insect Collection and Rearing

Using the sweep-netting technique for insect collection, adults of Musca domestica were gathered from distinct locations within four diverse cities in Punjab, Pakistan: Bahawalpur (29.3544° N, 71.6911° E), Lodhran (29.5467° N, 71.6276° E), Rahim Yar Khan (28.4212° N, 70.2989° E), and Multan (30.1575° N, 71.5249° E). The collection of housefly samples from privately-owned livestock farms was conducted with the cooperation of the proprietors, and it did not necessitate specific permits since the house fly is not categorized as an endangered species. Consequently, no permission from any relevant authority in Punjab, Pakistan, was required.

The acquired houseflies from diverse locations were transported to the laboratory and individually reared within meshed plastic jars measuring 34×17 cm. Adult flies were placed in these jars and provided with a sustenance mixture of powdered milk and sugar (1:1

ratio). To ensure hydration, a cotton wick saturated with water was placed in a separate Petri dish, and it was regularly moistened using a micro syringe to prevent desiccation.

For the larvae, an artificial diet was utilized. A combination of yeast, powdered milk, sugar, and water was prepared as feed in the proportions of 0.3:0.3:1:4, respectively, following the methodology outlined by Bell et al. in 2010. All specimens were maintained under controlled laboratory conditions, with the house flies experiencing a temperature of 25±2 °C, relative humidity of 60±5%, and a 12:12 (L:D) hours light-dark photoperiod.

Bioassays were conducted using the first-generation adults from the field population. Additionally, a laboratory susceptible strain was maintained, derived from a population of houseflies collected from an area with minimal or no chemical exposure. This strain served as a reference point for susceptibility testing in the laboratory.

Chemical Insecticides

Commercial formulated insecticides having broad spectrum activity were used for bioassays including a pyrethroid insecticide, Deltamethrin (Decis Super® 10 EC, Bayer Crop Sciences, Pakistan Limited) and a systemic neonicotinoid Thiamethoxam (Actara® 25 WG, Syngenta, Pakistan Limited).

Bioassays Procedure

The method of dosed contacting of insects was used to test the toxicity of insecticides for flies. The house flies were employed for bioassays procedures after being raised in the lab for one generation. Twenty-five 3 to 5 days old house flies were placed in treated jars with clean net and rubber coverings to allow for air exchange. Flies were transferred to clean jars after 15 minutes of exposure. The jars' tops were secured with a net, and wet cotton was placed on the net to provide humidity. Final mortality was determined 24, 48 and 72 hours after insecticide exposure, and all experiments were repeated three times. Bioassays were carried out in a standard laboratory setting of 25±2°C, 60±5% RH and a 12:12 (L:D) hours photoperiod.

Statistical Analysis

The data underwent analysis through repeated measures ANOVA, with statistical significance being recognized at a p-value of 0.05.

RESULTS

After 24 hours, there was a significant difference between the treatments for all the populations i.e., field populations and laboratory strains. Deltamethrin showed highest mortality rate of houseflies at 25.0 µg/ml dose and the lowest mortality was recorded at 5.0 µg/ml dose. Thiamethoxam showed highest mortality rate at 12.50 µg/ml dose and lowest mortality was recorded at 2.5 µg/ml dose. Lab population, a susceptible strain, was used to compare the susceptibility of all the field populations. Rahim Yar Khan's population was highly susceptible as compared to Multan, Bahawalpur and Lodhran populations. Lodhran's population was proved to be resistant as compared to the control population and other field populations (Table 1).

After 48 hours, there was also a significant difference between the treatments for all the populations. Deltamethrin showed highest mortality rate of houseflies at 25.0 µg/ml dose and the lowest mortality was recorded at 5.0 µg/ml dose. Thiamethoxam showed highest mortality rate at 12.50 µg/ml dose and lowest mortality was recorded at 2. µg/ml dose. Rahim Yar Khan's population was recorded highly susceptible as compared to Multan, Bahawalpur and Lodhran populations. Lodhran's population was proved to be resistant as compared to the control population and other field populations (Table 2).

After 72 hours, there was again a significant difference between the treatments for all the populations. Deltamethrin showed highest mortality rate of houseflies at 25.0 µg/ml dose and the lowest mortality was recorded at 5.0 µg/ml dose. Thiamethoxam showed highest mortality rate at 12.50 µg/ml dose and lowest mortality was recorded at 2.5 recorded as highly susceptible population as compared to Multan, Bahawalpur and Lodhran populations. Lodhran's population was proved be resistant as

Table 1: Mortality percentage of House fly populations treated with various doses of deltamethrin and thiamethoxam after 24 hours of exposure.

Insecticides	Populations					
	Doses ($\mu g\ ml^{-1}$)	Laboratory Strain	Rahim Yar Khan	Bahawalpur	Lodhran	Multan
Deltamethrin	5.0	13.65±1.1d	6.15±0.7d	5.06±0.6d	4.18±0.5d	5.13±0.6e
	10.0	24.06±1.5c	13.0±1.1c	12.0±1.0c	11.18±0.9c	12.06±1.0d
	15.0	37.51±2.2bc	20.50±1.3b	18.18±1.2b	17.04±1.2bc	18.92±1.2c
	20.0	49.32±2.9b	27.02±1.8ab	25.21±1.7ab	23.85±1.6b	25.96±1.8b
	25.0	61.84±3.6a	36.41±2.1a	31.52±1.9a	30.18±1.9a	33.04±2.0a
Thiamethoxam	2.5	12.56±1.0d	4.18±0.5e	3.96±0.4d	3.51±0.4d	4.0±0.5d
	5.0	24.96±1.7c	11.39±0.9d	10.46±0.9c	9.98±0.9c	10.56±0.9c
	7.50	37.08±2.2b	19.96±1.3c	16.18±1.2b	18.18±1.2b	17.43±1.2b
	10.0	47.23±2.8ab	26.87±1.8b	25.09±1.7a	23.97±1.6ab	25.16±1.7ab
	12.50	56.12±3.3a	34.42±2.0a	30.12±1.9a	29.12±1.9a	32.15±2.0a

Table 2: Mortality percentage of House fly populations treated with various doses of deltamethrin and thiamethoxam after 48 hours of exposure

Insecticides	Populations					
	Doses (μg/ml)	Laboratory Strain	Rahim Yar Khan	Bahawalpur	Lodhran	Multan
Deltamethrin	5.0	32.12±2.0d	14.15±1.1e	13.96±1.1d	12.18±1.0e	14.0±1.1d
	10.0	41.08±2.3c	27.29±1.8d	23.03±1.6c	21.31±1.4d	25.91±1.7c
	15.0	58.91±3.4bc	39.91±2.3c	38.86±2.2bc	36.51±2.1c	37.28±2.2bc
	20.0	69.21±3.9b	52.21±3.1b	48.0±2.9b	49.31±2.9b	51.05±3.0b
	25.0	82.77±4.3a	69.18±3.9a	65.12±3.7a	65.32±3.8a	67.22±3.8a
Thiamethoxam	2.5	25.29±1.7d	9.50±0.9e	7.02±0.8e	6.76±0.70d	7.96±0.8d
	5.0	39.55±2.3c	24.03±1.6d	21.92±1.4d	18.61±1.2c	19.32±1.3c
	7.50	58.0±3.4bc	38.31±2.2c	32.13±2.0c	29.50±1.9b	30.02±1.9b
	10.0	66.35±3.8b	54.53±3.2b	51.69±3.0b	47.0±2.8ab	49.17±3.0ab
	12.50	80.50±4.3a	73.48±4.1a	69.07±3.9a	63.93±3.7a	65.32±3.8a

Table 3. Mortality percentage of House fly populations treated with various doses of deltamethrin and thiamethoxam after 72 hours of exposure

Insecticides	Populations					
	Doses (μg/ml)	Laboratory Strain	Rahim Yar Khan	Bahawalpur	Lodhran	Multan
Deltamethrin	5.0	52.53±3.2cd	29.95±2.0d	26.23±1.8d	23.96±1.7e	27.53±1.8d
	10.0	60.0±3.5c	56.35±3.3c	49.91±3.0c	49.56±3.0d	51.50±3.1c
	15.0	82.32±4.3b	79.0±4.2b	76.33±4.1b	75.42±4.1c	77.07±4.1b
	20.0	100±0.00a	97.5±3.8a	93.05±3.6ab	91.50±3.5b	93.55±3.6ab
	25.0	100±0.00a	100±0.00	100±0.00	100±0.00	100±0.00a
Thiamethoxam	2.5	51.50±3.0d	12.45±1.0d	10.55±0.9d	10.12±0.9d	11.95±1.0d
	5.0	63.29±3.7c	49.35±2.9c	46.50±2.8cd	45.92±2.8cd	47.35±2.9cd
	7.50	81.32±4.2b	62.60±3.6bc	57.32±3.4c	55.04±3.3c	59.40±3.4c
	10.0	96.12±2.8a	80.0±4.2b	77.15±4.1b	76.38±4.1b	78.56±4.2b
	12.50	100±0.00a	100±0.00a	100±0.00a	100±0.00a	100±0.00a

compared to the control population and other field populations (table 3).

DISCUSSION

M. Domestica is one of the most widespread insect pests found suitable feeding and breeding environments in unsanitary conditions and badly maintained dairy or cattle facilities, which leads to disease transmission (Khan *et al*., 2012). In the current study, the susceptibility of houseflies from four different localities of Punjab, Pakistan was determined against deltamethrin and thiamethoxam. Deltamethrin was proved to be more effective as compared to thiamethoxam when used against houseflies in the livestock farms. Several researchers have reported different studies on the resistance, susceptibility and mortality rates of houseflies against various insecticides.

On cattle and poultry farms all around the world, pyrethroid-resistant house fly populations have been discovered. Resistance to pyrethroids has also been discovered in Florida dairy farms, with populations of flies more than 20-fold resistant to permethrin and 10-fold resistant to beta cyfluthrin (Kaufman et al., 2010). Resistance to pyrethroids has been reported in the population of flies on dairy farms in Pakistan: resistance ratio (at LC50) 5.73–18.31 for deltamethrin (Khan et al., 2013). In the Tyumen area of Russia, the native population of house flies in Nizhnaya Tavda village developed an unusually high resistance to pyrethroids after their long-term usage in pig and calf barns, with a stronger resistance to the more successful formulations. Despite the widespread use of neonicotinoid pesticides, the field house fly population investigated did not show resistance to thiamethoxam (RR = 1.12). Resistance to neonicotinoids has been observed in wild populations of the house fly by researchers from several nations. According to Khan et al. (2015), thiamethoxam resistance varied among flies gathered in different parts of Pakistan: RR (at LC50 values) ranged from 7.66 to 20.13.

Our findings aligned with those of previous research, which indicated that all houseflies subjected to deltamethrin treatment exhibited mortality only after a 24-hour exposure to a dosage of 25ppm. This suggests that applying deltamethrin at a concentration of at least 25 ppm proved efficacious in eliminating adult houseflies. It's worth noting that variations in flying patterns of houseflies following aerial spraying with deltamethrin could contribute to discrepancies in mortality rates across repeated experiments. In light of these outcomes, this study supports the practical viability of utilizing deltamethrin for effective housefly control.

Conclusion

The study revealed that the use of deltamethrin is more effective, as compared to thiamethoxam, to control houseflies in livestock farms. Hence, it can be recommended for effective control of houseflies for sustainable animal production.

REFERENCES

Abbas, N., Crickmore, N. & Shad, S. A. (2015). Efficacy of insecticide mixtures against a resistant strain of house fly (Diptera: Muscidae) collected from a poultry farm. *International Journal of Tropical Insect Science*, *35*(1), 48–53.

Abbas, N., Ijaz, M., Shad, S.A. & Khan, H. (2015b). Stability of field-selected resistance to conventional and newer chemistry insecticides in the housefly, Musca domestica L. (Diptera: Muscidae). *Neotrop, Entomol*, 44, 402-409.

Abbas, N., Khan, H.A.A. & Shad, S.A. (2014). Cross resistance, genetics, and realized heritability of resistance to fipronil in the housefly, Musca domestica (Diptera: Muscidae): a potential vector for disease transmission. *Parasitol*, 113, 1343–1352.

Anand, S.S., Kim, K.B., Padilla, S., Muralidhara, S., Kim, H.J. & Fisher, J.W. (2006). Ontogeny of hepatic and plasma metabolism of deltamethrin in vitro: role in age-dependent acute neurotoxicity. *Drug Metabolism and Disposition*, 34, 389-397.

Babar, M., Nawaz, M., Shahani, A., Khalid, M., Latif, A., Kanwal, K., Ijaz, M., Maqsood, Z., Amjad, I., & Khan, A. (2022). Genomic Assisted Crop Breeding Approaches For Designing Future Crops To Combat Food Production Challenges. *Biological And Clinical Sciences Research Journal* **2022**.

Bhanu, Shrivastava. et al. (2011). Impact of Deltamethrin on Environment, use as an Insecticide and its Bacterial degradation – A preliminary study. *International Journal of Environmental Sciences,* 1, 984-992.

Cetin, H., Erler, F., Yanikoglu, A. (2009). Survey of insect growth regulator (IGR) resistance in houseflies (Musca domestica L.) from southwestern Turkey. *J Vect Ecol,* 34, 329–337.

Fotedar, R. (20010. Vector potential of houseflies (Musca domestica) in the transmission of Vibrio cholerae in India. *Acta Tropica,* 78 (1), 31–34.

Jeschke, P. & Nauen, R. (2008). Neonicotinoids-From zero to hero in insecticide chemistry. *Pest Management Science*, 64 (11), 1084–1098.

Kamal, H., Minhas, F. U. A. A., Farooq, M., Tripathi, D., Hamza, M., Mustafa, R., ... & Amin, I. (2019). In silico prediction and validations of domains involved in Gossypium hirsutum SnRK1 protein interaction with cotton leaf curl Multan betasatellite encoded βC1. Frontiers in Plant Science, 10, 656.

Kaufman, P. E., Nunez, S.C., Mann, R.S., Geden, C.J., & Scharf, M.E. (2010). Nicotinoid and pyrethroid insecticide resistance in houseflies (Diptera: Muscidae) collected from Florida dairies. *Pest Management Science*, 66, 290–294.

Khalid, M. N. (2022). *Fundamentals of Agriculture* (Vol. 1). Vital Biotech Publications.

Khalid, M. N., Abdullah, A., Ijaz, Z., Naheed, N., Hamad, A., Sheir, M. A., Shabir, F., Parveen, K., & Khan, M. D. (2021). Application and Potential Use of Advanced Bioinformatics Techniques in Agriculture and Animal Sciences. *Ind. J. Pure App. Biosci* **9**, 237-246.

Khan, H.A.A., Akram, W. & Shad, S.A. (2013). Resistance to conventional insecticides in Pakistani populations of Musca domestica L. (Diptera: Muscidae): a potential ectoparasite of dairy animals. *Ecotoxicology,* 22, 522–527.

Khan, H.A.A., Akram, W., Iqbal, J. & Naeem-Ullah U. (2015). Thiamethoxam resistance in the housefly, Musca domestica L.: current status, resistance selection, cross-resistance potential and possible biochemical mechanisms. *PLoS One,* 10(5), 125-850.

Khan, H.A.A., Shad, S.A. & Akram, W., (2012). Effect of livestock manures on the fitness of housefly, Musca domestica L. (Diptera: Muscidae). *Parasitol. Res.,* 111, 1165-1171.

Kristensen, M. & Jespersen, J. B. (2008). Susceptibility to thiamethoxam of Musca domestica from Danish livestock farms. *Pest Management Science,* 64, 126–132.

Levchenko, M. A., & Silivanova, E. A. (2019). Synergistic and antagonistic effects of insecticide binary mixtures against house flies (Musca domestica). *Regulatory Mechanisms in Biosystems*, *10*(1), 75–82.

Mukhtar, M. K., Waliat, S., Khan, S. Y. & Amjad, N. (2021). Toxicity and Resistance Status of Musca domestica against Bifenthrin and Dimethoate from Bhalwal, Punjab, Pakistan. *Punjab University Journal of Zoology*, *36*(1), 119–123.

Scott, J.G., Liu, N.N., Kristensen, M. & Clark, A.G. (2009). A case for sequencing the genome of Musca domestica (Diptera: Muscidae). *J. Med. Entomol.,* 46, 175-182.

Sharififard, M. & Safdari, F. (2013). Evaluation of resistance or susceptibility of the housefly, Musca domestica L., of semi-industrial livestock farms to some pyrethroid insecticides in Ahvaz, southwestern Iran. *Jundishapur J. Health Science,* 5, 201-206.

Suwannayod, S., Sukontason, K.L., Pitasawat, B., Junkum, A., Limsopatham, K., Jones, M. K., Somboon, P., Leksomboon, R., Chareonviriyaphap, T., Tawatsin, A., Thavara, U. & Thavara, U. (2019). Synergistic toxicity of plant essential oils combined with pyrethroid insecticides against blow flies and the housefly. *Insects,* 10, 178-194.

Timothy, C.M. (2012). Mammalian Toxicology of Insecticides. Royal Society of Chemistry in Toxicology, 1(12), 490.

Tomizawa, M. & Casida, J.E. (2005). Neonicotinoid insecticide toxicology: mechanism and selective action. *Annu Rev Pharmacol Toxicology,* 45, 247–68.

Zahoor, M.K., Zahoor, M.A., Mubarik, M.S., Rizvi, H., Majeed, H.N., Zulhussnain, M., Ranian, K., Sultana, K., Imran, M. & Qamer, S. (2020). Insecticidal, biological and biochemical response of Musca domestica (Diptera: Muscidae) to some indigenous weed plant extracts. Saudi J. *Biol. Science,* 27, 106-116.

Zafar, M. M., Razzaq, A., Farooq, M. A., Rehman, A., Firdous, H., Shakeel, A., ... & Youlu, Y. (2022). Genetic variation studies of ionic and within boll yield components in cotton (Gossypium Hirsutum L.) Under salt stress. Journal of Natural Fibers, 19(8), 3063-3082.

Zafar, M. M., Rehman, A., Razzaq, A., Parvaiz, A., Mustafa, G., Sharif, F., ... & Ren, M. (2022). Genome-wide characterization and expression analysis of Erf gene family in cotton. BMC plant biology, 22(1), 134.