SURVEILLANCE AND MANAGEMENT OF MOSQUITO SPECIES WITH SPECIAL EMPHASIS ON THE DENGUE VECTOR(S) IN PESHAWAR VALLEY

BY

GUL ZAMIN KHAN

A Thesis submitted to The University of Agriculture, Peshawar, Pakistan, in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (PH.D.) IN ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY,
FACULTY OF CROP PROTECTION SCIENCES,
THE UNIVERSITY OF AGRICULTURE,
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The author was born on February 21, 1975 at village Sunigram, District Buner, Khyber Pakhtunkhwa, Pakistan and is the middle son of his parents.

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(Gul Zamin Khan)
SURVEILLANCE AND MANAGEMENT OF MOSQUITO SPECIES WITH SPECIAL EMPHASIS ON THE DENGUE VECTOR(S) IN PESHAWAR VALLEY

Gul Zamin Khan and Imtiaz Ali Khan
Department of Entomology, Faculty of Crop Protection Sciences
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ABSTRACT
The present study was planned to investigate the population dynamics and habitats of economically important mosquito species with special emphasis on *Aedes* spp., the dengue vector in Peshawar Valley during 2011 - 2012. Data were collected from different habitat types in Peshawar, Nowshera, Mardan and Charsadda. Efficacy of different synthetic and natural insecticides as well as IGRs was tested in various concentrations against the mosquito species. In the irradiation experiments various doses of Cobalt 60 were tested to determine the optimum dose for causing male sterility in *Aedes albopictus*. The result revealed that population of *Culex* spp. was highest in Peshawar and lowest in Charsadda. The mean abundance of *Aedes albopictus* was highest in Mardan and lowest in Charsadda. *Culex* spp. populations peaked during September-October while *Aedes* spp. during October-November. Highest mean abundance (5300) of the specimen was found in sewage water and lowest in flower pots (11). At all the tested sites sewage water was found more favorable for breeding of *Culex* spp. while, irrigation channels, scrap, water tanks and pot vases for *Aedes* spp. The ovitrap index revealed higher population of *Culex* spp. in the indoor while that of *Aedes* spp. in the outdoor location. The indoor ovitrap index of *Culex* spp. was highest in Mardan (16.05%) and lowest in Peshawar (9.38%). The outdoor ovitrap index of *Aedes* spp. was highest in Nowshera (19.3%) and lowest in Charsadda (7.83%). The vector control *In Vitro* experiments showed significant differences in larval and adult mortalities as affected by the different synthetic insecticides, IGRs and plant extracts tested in various concentrations. Spatial variation in the mortality of both larvae and adults were observed in response to the insecticides. This variable response might be due to the intra-specie genetic variations from selection pressure of insecticides resulting into the development of resistance in the mosquitoes. The IGRs exhibited LC$_{50}$ and LC$_{90}$ in range of 0.002 to 0.016 ppm and 0.008 to 0.115 ppm, respectively. The IGRs yielded significant inhibition (79 to 99.5%) in adult emergence in the 3rd instars larvae of both *Aedes* and *Culex* spp. The IGRs were classified in terms of the tested parameters in order of Pyriproxyfen 1.0 WDG > Pyriproxyfen 0.5 WDG > Methoprene. In the field experiments, Pyriproxyfen 1.0 WDG @ 0.1g/m$^3$ resulted in negligible adult emergence over a period of six months in water samples from different treated habitats. Crude plant extracts were tested for larvicidal activity against 3rd and 4th instars of *Culex* and *Aedes* spp. Parthenium showed lowest LC$_{50}$ (0.849-1.543%), LC$_{90}$ (1.875-2.882%) while Stevia extract the highest LC$_{50}$ (2.086-2.889%), LC$_{90}$ (5.836-8.533%) against the 3rd and 4th instar larvae of both the species after 24-48 hrs exposure periods. The larvicidal efficiency of plant extracts were ranked in order of Parthenium > Neem extract > Chrysanthemum > Neem oil > Stevia extract. The results of SIT experiments with *Aedes albopictus* revealed irradiation dose of 40-60 Gy as optimum for acceptable number of mating (7-8) of sterile males with wild female, negligible fecundity and subsequent hatching in no choice tests.
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I have no words to express my deepest sense of gratitude to Almighty Allah, the Most Merciful, and the Beneficent, Who bestowed upon me the courage to complete this project. All respects for the holy Prophet Muhammad (SAW), who is forever model of guidance and knowledge for humanity.

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(Gul Zamin Khan)
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I. INTRODUCTION

Mosquitoes are highly advanced dipterous insect pests that negatively influence the fitness of human beings and animals worldwide. They are grouped in 39 genera with more than 3500 species in the world. Three genera; *Anopheles*, *Aedes* and *Culex* are the key vectors of pathogens due to their induced haematophagy (Reinert *et al*., 2004). A huge population of mosquitoes can arise anywhere under favorable environmental conditions. Female mosquitoes while seeking blood meal for egg production make a painful bite that result in the transmission of a number of disease causing agents to humans and animals as well. Among insect transmitted diseases, more than 700 million people annually are affected by mosquitoes (Aregawi *et al*., 2008). Mosquito-borne pathogens include parasites such as plasmodium, filarial (*Wuchereria bancrofti* and *Brugia*), arboviruses like West Nile, Yellow Fever, Dengue and Encephalitis (WHO, 2008).

**Dengue fever**

Among the Mosquitoes bearing diseases, dengue fever is the most important disease caused by the family Flaviviridae having single stranded RNA virus with four different serotypes (Gubler, 1998) and prevailed in the tropics and sub tropics (Arunachalam *et al*., 2009; WHO, 2008). The disease is reported from both the rural and urban areas because the vectors are equally anthropophillic and prefers those habitats which are in proximity to humans (Wan *et al*., 2009). The vector mosquitoes acquire the virus from an infected person and transmit it to a healthy person that results in the appearance of disease symptoms within 5-7 days. These symptoms comprise high fever, rashes, rigorous headache, joint and muscular pain, nausea, vomiting and pain in eyes as well. Each year fifty to hundred million cases of dengue fever (DF) and 500,000 cases of Dengue Hemorrhagic Fever (DHF) is reported by World Health Organization (Gibbons and Vaughn, 2002; WHO, 2008).

**Dengue fever in Pakistan**

In Pakistan, dengue fever is a promising disease and a rising health issue, its primary vector *Aedes aegypti* was collected from Karachi, Larkana, Peshawar, Dera Ismail Khan and Lahore during 1934 extending to Kohat-Hangu in 1949. After 1950 its distribution was significantly decreased due to malaria vector elimination program
The comeback of *Aedes aegypti* was in two events, first in 1980s in south and second in 1993 in north. A decade after, four serotypes of dengue virus were recorded from Pakistan in 2005 (WHO, 2008). The proven of dengue was not articulated until 2005; however, it was mostly confined to the southern area (Karachi) of Pakistan. Movement of dengue affected people from the endemic areas to non affected areas serves as a main source of dengue fever spreading. Trading of 2nd hand tires is another source of spreading dengue virus in Pakistan. Desiccated eggs in tires may serve as vector transmission from dengue endemic countries. In 2007, Basal and Thatta Khalil villages in the District Attock were reported the remarkable locality having dengue symptoms which affected 80% of the population. The year 2011-12 was verified to be worse in regard to dengue in Pakistan where 27562 cases were reported in Punjab and 8457 cases in Swat (Health Deptt.) Pak., 2012 and 2013) which need proper attention.

The rural, semi-urban and urban communities are at high risk of increasing epidemics of dengue virus in Pakistan. The rural community (70% of the total population) living in houses with no proper sanitation, long hours power load shedding and no protection from mosquito bites are therefore, more exposed to dengue and other vectors easily. Moreover, the vast agricultural lands, presence of nine major rivers: Swat, Kabul, Kuram, Chitral, Kunhar, Indus, Sutlaj, Ravi and Chanab; several dams: Warsak, Turbela, Tanda, Zaibi and Ghazi Barota and open network of agricultural channels from these reservoirs provides plenty of breeding places for all kind of fresh water mosquitoes (Khan et al., 2011). However, the semi-urban and urban communities are overcrowded due to internal displacement caused by devastating floods in the country, poverty and insecurity due to terrorism. This scenario supports the spread of infectious diseases and as a result a huge number of epidemics/outbreaks happen in different areas of the country (Jahan, 2011; Jahan and Amna, 2012).

Although dengue is a serious health problem in many areas of Pakistan and having potential of becoming established in other areas of Pakistan (Suleman et al., 1996), no effective integrated national surveillance system or coordinated dengue vector control program is in place at this time. There is a general lack of information about this vector and few research organizations are working on the vector control throughout the country. Therefore, mosquito fauna and epidemiology of vector is poorly studied. Thus there is dire need to address the situation and devise appropriate methods of vector control.
management and establishment of disease surveillance agencies in the affected areas of Pakistan.

1.1 Entry and distribution of dengue vectors in Pakistan

Vector Control

Presently, vaccines are not available for curing dengue virus infection at the world level. Therefore, the control of spreading and biting of vector mosquito is the only way of dengue management (WHO, 2008). But still very little attempts have been initiated for reducing the number of dengue infected cases through vector control. Fumigation methods are usually adopted to kill adult mosquitoes. A combination of larvicides and fumigants having adult knock down properties, may decrease the mosquito population. But the uses of the chemicals, although quick and efficient, create toxic effects on non target organisms and environment. They also have negative entomological threat of developing resistance of mosquitoes to insecticides (Jirakanjanakit et al., 2007). Therefore, these problems demand the necessity for
adopting alternative management tactics (Karunaratne and Hemingway, 2000).

**Surveillance and key larval habitats**

Management of larval habitats of dengue vector is an essential component of dengue control programs (Edelman, 2007; Impoinvil et al., 2007; Ottesen, 2006). The life cycle of mosquitoes requires the development of larvae and pupae in habitats containing water with varying physical and chemical properties depending on mosquito species (Muturi et al., 2007; Shililu et al., 2003). Therefore, prevention and control should be targeted by avoiding human contact with mosquitoes, reduction of adult mosquito populations and elimination of mosquito’s larval habitats (Gubler, 1998). Ovitrap surveillance is an effective tool in determining the occurrence, population dynamics and to identify the key areas for the control of *Aedes* species (Chen et al., 2005; Chen et al., 2006; Lagrotta, 2008).

*Aedes* species are strongly associated with human surroundings, where outdoor and indoor artificial containers like buckets, drums, flowerpots, vases and tires make adequate habitats for larval development (Chadee, 2009; Focks, 2003; Pages et al., 2006; Service, 1992). In addition, human behavior is one of the important factors influencing the epidemiology of dengue fever (Chadee et al., 2005; Gubler, 2005; Guzman and Kouri, 2003). Trade also helps in distribution of *Aedes aegypti* as the imported tires in warehouses at Landi Kotal (KPK Province) were identified positive for it. *Aedes aegypti* survival at Landi Kotal through all seasons despite control measures indicates its latent of becoming customary in other area of Pakistan (Suleman et al., 1996). Therefore, knowledge about the local vector habitat profiles, population dynamics, distribution trend and relative abundance, etc. are important for devising effective management strategies for the mosquito vectors.

**Resistance in Dengue Vector**

Resistance in mosquitoes has been explained as the acquirement of fitness of a strain to continue doses of a toxicant that would kill the majority of the individuals in an average population of the similar species (Hemingway and Ranson, 2000; WHO, 1970). Resistance to insecticides is an essential issue and the information on the presence of resistance may add in the development of an insecticide resistance monitoring program and may help in devising strategies for *Aedes* management and consequently
the spread of dengue (Polson et al., 2011). Extent of resistance in Aedes is not fully known but, if prevalent, may create difficulties in future vector control (Hemingway et al., 2004). Therefore, knowing the status of resistance level of Aedes and Culex species to various groups of insecticides may help in devising improved management tools.

Insect Growth Regulators (IGRs)

IGR is a special new class of insecticides complex in addition to four major chemical groups; chlorinated hydrocarbons, organophosphates, carbamates, and parathryoid that influence insect mortality as larvicides in an environmentally safe way (Suman et al., 2013). Thus the use of juvenile hormones mimics and chitin synthesis inhibitors in the form of IGRs (Hotakoshi et al., 1987; Lee, 2001; Nayar et al., 2002; Sihuincha et al., 2005; Trayler et al., 1994; Vythilingam et al., 2005) for working out integrated management environment friendly approaches against mosquitoes (Delatte et al., 2008; Wang et al., 2000) are the key areas to be utilized for the vector control.

Botanical extracts

Utilizing plant crude extracts in insect control has numerous interesting attributes due to their extensive biodegradation capability, less environmental hazards and rich source of various bioactive chemicals. These bioactive plant materials have drawn significant interest in mosquito management (Wang et al., 2000). This study deals with screening of locally existing herbs for exploring their mosquito larvicidal properties (Rahuman et al., 2008a; Rahuman et al., 2008b).

Towards the Sterile Insect Technique (SIT) of Mosquitoes

In Sterile Insect Technique (SIT) the laboratory reared sterile males are mass released into natural environment for the purpose of suppressing or eliminating the target pest by disturbing its progeny production (Dame, 1985; Snow, 1987). SIT has been used extensively and effectively to control various insect pest species (Dyck et al., 2005). In mosquito control, the Sterile Insect Technique dates back to 1960s when sterile Aedes aegypti males were released in Florida (USA), with the intention to reduce Aedes population (Morlan et al., 1962). This was followed by considerable studies on mosquito SIT (Benedict and Robinson, 2003); pilot field trial in northern Sudan to determine the feasibility of SIT to control the African malaria vector An. arabiensis (Klassen, 2009).
Having potential for different species of mosquitoes, efforts for SIT tactics of *Aedes* species are also in progress at Insect Pest Control Laboratories (IPCL), Seibersdorf, IAEA, Vienna, Austria. Baseline data on the working out effective radiation doses for male sterility and their subsequent mating compatibility with wild females are important towards the development of SIT of mosquitoes in Pakistan. This technique can be integrated with other control strategies are important to know and was therefore, included in the current studies.

Keeping in view, the increasing trend of high mortalities from mosquito species vectoring dengue pathogens, there is a dire need to make short and long term planning for its management. The present studies were therefore, designed to develop long term sustainable strategies for the control of dengue vector in Pakistan. These studies will provide baseline entomological data which will help in better management of mosquitoes through the development of area wide integrated pest management strategies including planning for sterile insect technique in collaboration with international agencies. The current study was conducted with the following objectives.

1. To determine relative abundance of prevailing mosquito species in Peshawar valley.
2. To locate important breeding sites of *Aedes* and *Culex* spp. in Peshawar valley.
3. To determine the Susceptibility/resistance of field strains *Aedes* and *Culex* spp. to commonly used insecticides.
4. To assess the efficacy of various growth regulators and botanical extracts on larval mortality and growth inhibition of *Culex* and *Aedes* mosquitoes.
5. To determine optimum radiation doses for partial/complete sterility of dengue vectors.
II. REVIEW OF LITERATURE

2.1 Entomological Surveillance

Khan and Salman, (1969) found Aedes scatophagoides, Aedes caecus, Culseta longiareolafa and Culex univittatus during in an ecological survey of the mosquitoes fauna of Changa Manga National Forest. Aedes species were found positively phototropic with maximum biting hours of 14:00 to 16:00.

Suleman et al., (1996) reported the incidence of Aedes aegypti in Landi Kotal during entomological survey. The route of entry of this species in this area was linked to the trade of used tires from the port city of Karachi. The residual spray of Malathion reduced abundance of Aedes aegypti in the sites. Aedes aegypti reappeared during the hot months from the over wintering eggs. Population increased during late August despite the other round of spray using fenthion and other larvicides. The survival and spread of this mosquito to neighboring areas of Landi Kotal despite of all control measures indicated its potential of becoming established in other areas of Pakistan.

Sharma and Hamzakoya, (2001) identified Anopheles stephensi as a main vector of urban malaria. They further reported that Aedes aegypti has now spread widely in all the islands and poses alarming threats of Dengue fever in the future.

Kiyoshi et al., (2002) performed mosquito collections survey by using bed net and dry ice methods in and around Karachi. Female of Culex tritaeniorhynchus were processed for virus isolation. Japanese encephalitis virus was not detected in these mosquitoes. However, four strains of West Nile virus were detected in Culex tritaeniorhynchus. It was concluded that the Japanese encephalitis virus is uncommon in Karachi area.

Petersen and Marfin, (2002) identified 149 persons with West Nile virus-related illness during their surveillance study. Peak incidences were found in late summer, although onset has occurred from July to December.

Herrel et al., (2004) used parathyroid spray catching method for mosquitoes’ survey in vegetation and animal sheds. 98.8 percent mosquitoes were collected from
indoor sites while outdoors resting-sites accounted for only 1.2% of total anopheline densities. Seasonal abundance was negatively affected with low rainfall and high temperatures in the area.

Chen et al., (2005) determined the abundance and allocation of dengue vectors; *Aedes aegypti* and *Aedes albopictus*. The ovitrap surveillance indicated that *Aedes aegypti* and *Aedes albopictus* were present both outdoors and indoors. The density of *Aedes aegypti* was considerably more than *Aedes albopictus* by 3 - 50 folds. No significant differences were found in the larval numbers of *Aedes aegypti* between indoors and outdoors, thus implicating that adult gravid female *Aedes aegypti* are present both indoors and outdoors and they do oviposit indoors and outdoors.

Chen et al., (2006) conducted ovitrap surveillance in four dengue endemic areas to verify the percentage and allocation of mixed breeding of both *Aedes aegypti* and *Aedes albopictus*. Mixed breeding percentage for both indoors and outdoors accounted for 10 to 32% from the total collected ovitraps. *Aedes aegypti* was observed at a higher rate than *Aedes albopictus* in the ovitraps. This study indicated that ovitrap is a sensitive tool to attract gravid females of more than one mosquito’s species to oviposit in the container.

Pages et al., (2006) stated that over the last 50 years *Aedes albopictus* (Skuse) has spread to all continents. This anthropophilous species is capable of adapting to most climates. Being regarded as a secondary vector of dengue disease, it has been observed to be capable for transmission of arbovirus under laboratory conditions. Tiger mosquito has played a key role in the transmission of arbovirus in the invaded locations (dengue fever and chikungunya).

McMahon et al., (2008) indicated the mosquito’s species composition in tires in Manitoba (Canada). More than 25% of the 1,142 sampled tires hold a total of 32,474 mosquito larvae and pupae. *Culex restuans* made up 95 percent of the larvae collected for the months of summer. *Culex inornata* and *Culex tarsalis* attained their maximum numbers in July and August, respectively.
Jayasooriya et al., (2009) reported that *Aedes aegypti* and *Aedes albopictus* density was determined by immature (larvae and pupae) surveys. They concluded that identification of finer-scale DF/DHF risk areas using the geographical information system, global positioning system and application of vector control interventions in high-risk Grama Niladari areas is very useful for DF/DHF prevention and control.

Paupy et al., (2009) reported that *Aedes albopictus* is invasive species in nature that may be found in all the continents. This species is considered as a secondary vector of dengue virus and has recently been proposed to play a role in the spread of Chikungunya virus as well.

Hamady et al., (2010) found that the Asian tiger mosquito lives longer in the indoor environment. They also reported increased in fecundity and night time biting activity in indoor domestic females, although their body size was similar to the recently colonized females. The data suggested that accommodation of *Aedes albopictus* to indoor environment may enhance its life time, blood feeding, annoyance and thus vectorial ability both in terms of enhanced vector population density and vector-host contact.

Tariq et al., (2010) found 18 Towns of Karachi city positive for Dengue vector mosquitoes. *Aedes aegypti* was recorded in Orangi (69.00), Baldia (211.00), SITE (24.16), Liaqatabad (2382.83), Gulshan-e-Iqbal (53.16), Korangi (22.66) and Shah Faisal Town (282.33) continuously, whereas *Aedes unilineatus* was noted in two Towns, SITE (96.66) and G.I. (140.83).

Gavaudan et al., (2011) reported that integrated wide-sized ovitrap monitoring is a helpful tool in any good pest-control strategy. The *Aedes albopictus* population dynamics were calculated over a four-year period in the town of Pesaro (Marche, Italy), using ovitraps as monitoring tool. The monitoring system was proposed as cost-effective and easily available system for extensive vector surveillance.

Gratz, (2011) documented that the majority of introductions of vector mosquitoes were actually due to transportation of resting eggs in tires. *Aedes albopictus* was found as proficient vector for a minimum of 22 arboviruses, including all four
dengue serotypes. He stated that several arboviruses are readily spread by *Aedes albopictus* to laboratory birds and animals, and have normally been isolated from wild-caught female mosquitoes of this species, mostly in America. *Aedes albopictus* is anthropophilic throughout its range and persists to spread, displacing *Aedes aegypti* in various regions.

Jahan, (2011) is of the view that dengue is a prevalent mosquito-borne disease in human beings, which recently has turned into an important public health problem in Pakistan.

### 2.2 Larval habitat

Minakawa et al., (1999) analyzed spatial heterogeneity of mosquito species inhibited mosquito larvae having 128 aquatic habitats, where 10,538 culicine and 2,209 anopheline larvae were collected. The habitats were characterized based on PH, size and distance to the nearest house. *An. gambiae* was less common (31.4%) while *An. arabiensis* was the predominant species (63.4%).

Blackwell and Johnson, (2000) tested the samples of *An. gambiae* breeding sites in rural sites in the Tanga region of Tanzania. Sites containing the largest numbers of *An. gambiae* larvae were small, shaded pools and rice fields.

Brian et al., (2002) involved school children, health volunteer teachers and local leaders supported by health professionals in a dengue control program. Discarded containers were either recycled for economic gain or removed from the vicinity through 37 clean-up campaigns. Control efficacy was found 99.7% in the site. Although wells and tanks were the major container types of *Aedes aegypti* productivity and discarded material was the source of 51% of the standing crop of *Aedes albopictus*. *Aedes albopictus* larval removal from the target area resulted in 86-98% control.

Ali et al., (2003) found breeding of *Aedes albopictus* in the neglected households. They developed a correlation of disease occurrence and the potential breeding containers with the recommendations of considering the entire possible household during the breeding habitats management program.
Kuslimawathie and Siyambalagoda, (2005) observed the distribution and breeding sites of *Aedes aegypti* and *Aedes albopictus*. The majority (96%) of breeding sites of *Aedes albopictus* and *Aedes aegypti* comprised of water storage containers, discarded receptacles and tires. Breeding sites of *Aedes albopictus* and *Aedes aegypti* differed from one locality to another as well as from one time period to another.

Piyaratnea *et al.*, (2005) explained the importance of physico-chemical characters of pooled and flowing water in a stream that breed mosquitoes species mainly malaria vectors; *Anopheles culicifacies* and *An. varuna*. The former species was positively related to temperature while, the later species to calcium only. Moreover, *An. culicifacies* was also found to be associated to vegetation and light, and negatively related with the incidence of potential predators.

Sophie *et al.*, (2005) observed time, individual location of a person and surrounding environment of the house as important spatial and sequential determinants for the dengue infection. They suggested that immense difference of determinants for latest dengue infection in time and space should be considered into account when designing local dengue control strategy.

Aditya *et al.*, (2006) found a number of aquatic habitats with different physical and biological features that were hosting mix culture of mosquito species. Immature of mosquito species were significantly different in temporal variation in their relative and absolute numbers. The hosting water bodies were categorized into six types depending on the structural and size complication that clarified the observed variations in the species composition of larval habitats. Other factors like rainfall, temperature and related environmental features were found responsible for the species variation, which requires to be verified through further research.

Mukhtar *et al.*, (2006) highlighted the importance of waste water-irrigated sites and waste stabilization ponds for the production of medically important mosquitoes. Facultative ponds produced lower numbers of both *Culex* and *Anopheles* species. *Anopheles* species were the dominant in waste water irrigated sites. Proper elimination of grasses along the margins of the anaerobic ponds and modifications in the concrete design reduced the mosquito production, especially of *Culex* species.
Vezzani, (2006) reported *Culex pipiens*, *Aedes albopictus* and *Aedes aegypti* as artificial container-breeding mosquitoes. Cemeteries were found extremely appropriate habitats for these mosquitoes’ species due to availability of the different resources like blood, sugar substances, water-filled containers and shelter that they needed.

Azari, (2007) collected larvae of *Culex mimeticus*, *Culex pipiens*, *Culex theileri*, *Culex tritaeniorhynchus*, *Culex hortensis*, and *Culex territans* from 92 larval breeding sites. Most of the larvae were collected from the natural habitats (75.6%) such as river edges (6.5%), riverbed pools (28.2%), rain pools (47.8%), stream edges (9.4%), grasslands (1.9%), marshes (2.8%), and hoof-prints (3.4%) and others from artificial habitats (24.4%) including rice fields (32.1%), irrigation channels (7.1%), wells (16.4%), discarded irrigations tubs (33.1%), discarded tires (11.0%), and agricultural water storage pools (0.3%).

Zhou *et al.*, (2007) documented a significant cross-correlation between the vector population and larval habitat availability and a considerable autocorrelation in the vector population. Regression analysis demonstrated that house structure, elevation, age of the house, distance of a house to the River and tree canopy coverage significantly influenced adult mosquito abundance.

Erlanger *et al.*, (2008) compared the effects of entomological parameters; House Index (HI), Container Index (CI) and Breteau Index (BI) with dengue vector control, i.e. environmental management, chemical control, biological control and integrated vector management interventions. Integrated vector management (IVM) was found to be the most effective method to reduce the CI, HI and BI, which resulted in random combined relative effectiveness values of 0.12, 0.17 and 0.33, respectively.

Chena *et al.*, (2009) studied breeding sources of mosquito larvae grouped into eight different container types: plastic containers, plastic pails, bottles, earthen plates, natural containers, vases, cans and concrete tanks. A total of 262 containers were identified as potential breeding sites. However, only 65 containers (86.15% outdoors and 13.85% indoors) were found containing larvae. Among all types of containers, 50% of the total surveyed natural containers were positive with mosquito larvae. The study
indicated that *Aedes albopictus* was competent of breeding in a broad range of container types. Thus natural containers should be taken in respect to control these mosquitoes.

Rohani *et al.*, (2010) determined the habitat abundance of *An. maculatus* in malaria prevalent areas. *An. maculatus* mosquitoes preferred to rear in water compartments formed on the waterfall and river banks. The most common larval habitats were shallow pools (5.0-15.0 cm deep) with clean water, plants or float age and mud substrate. The mosquito also favored open or partly shaded habitations. Breeding habitats were usually located at a distance of 100-400 m from the adjacent human settlement. Alterations in breeding traits were also examined instead of breeding in slow flowing streams, most larvae bred in small water compartments along the river margins.

Albert and Lucy, (2011) analyzed nutrient content of *An. gambiae* mosquitoes at larval habitats using oxidation method. A positive correlation was observed between larval and algal densities. Water pH, total nitrogen and turbidity were positively associated whereas; pH was negatively correlated with larval density. The results indicated that water nutrients and algal contents in larval habitations of *An. gambiae* play vital and dual role in the resource ecology of these mosquitoes.

Marina *et al.*, (2011) collected data on larval habitat types, size, depth, distance to the neighboring houses, nature of the habitat i.e., artificial/natural, location related to sunlight, organic materials, type of substrate, vegetation and algae type and their presence. Principal component analysis indicated that the volume of the larval habitat and the existence of aquatic vegetation were the major features that explained the variations among various species.

Stein *et al.*, (2011) classified mosquito species on larval habitat size and presence of aquatic vegetation. In comparison, water permanence was second in importance. Type of larval habitat, pH and water temperature was less important in explaining the clustering of species.

Louis *et al.*, (2012) indicated that stagnant water bodies could be efficient breeding habitats for *An. Arabiensis*. Larval abundance appeared to be influenced by macro-fauna, diversity, and predation pressure and flow velocity. Relative abundance of
larvae in artificial habitats was significantly lesser than that observed in naturally occurring ones. Such variations may be accounted for in part by varying pressures that could be associated with a specific habitat. The low larval abundance, which resulted from both biotic and a biotic factors, advocated that vector control measures targeting larval habitats are likely to be thriving tool.

2.3 Resistance to insecticides

Mori *et al.*, (2001) detected a relative linkage map of resistance for *Culex tritaeniorhynchus*. They found that insensitive Acetyl Cholinesterase (AChE) mediated organophosphate resistance is controlled by a single major gene (AChER) on chromosome 2, while the AChE structural gene (Ace) is located on chromosome 1.

Alongkot *et al.*, (2005) performed bioassays for determination of resistance level in the field collected *Aedes aegypti* and *Aedes albopictus*, respectively. The patterns of insecticide susceptibility to permethrin, Malathion and temephos of both *Aedes aegypti* and *Aedes albopictus* larvae were resolute. *Aedes aegypti* from all the sites were susceptible to Malathion but were resistant to permethrin. Temephos resistance was noticed in all strains of *Aedes aegypti*, except those from Nakhon Ratchasima. *Aedes albopictus* larvae had low resistance levels to all three insecticides, except Phatthalung and Mae Sot strains, which showed resistance to permethrin.

Chow and William, (2005) pointed out KT50 values for d-allethrin against *Aedes aegypti* (1.38 min) and *Culex quinquefasciatus* (8.36 min). Significant variations were observed between *Aedes aegypti* and *Culex quinquefasciatus* tested with prallethrin and d-allethrin. Longevity of *Culex quinquefasciatus* and *Aedes aegypti* species reduced more than 45% and 80%, respectively, after exposure to mosquito mats containing either prallethrin or d-allethrin. Blood-engorgement activity percentage for both the species was reduced to less than 25% and 70%, respectively after a 20 min exposure to the mats.

Hamdan *et al.*, (2005) used laboratory-reared females of *Aedes Albopictus, Culex quinquefasciatus* and *Aedes aegypti* for studying resistance. Resistance development rate was measured by LC50 values. Higher resistance was observed in *Culex quinquefasciatus* larvae against malathion and permethrin as compared to *Aedes albopictus* and *Aedes aegypti*. Moreover, resistance to permethrin developed quicker than temephos and malathion.
Rapeeporn et al., (2005) reported that adult *Aedes aegypti* mosquitoes were examined for susceptibility tests against deltamethrin. Low levels of resistance were noticed among all sampled populations tested as compared to the susceptible strain, Bora (French Polynesia). Among the five tested populations, the PSC (Phasicharoen, Bangkok) and BKH (Bang Khen, Bangkok) populations demonstrated a higher level of deltamethrin resistance than the other three populations and cross-resistance against DDT was detected in these strains. Biochemical analysis confirmed a significant elevation of mixed function oxidizes enzyme activity in all tested populations.

Hidayati et al., (2011) carried out bioassay test against malathion with adult and larval stages of *Aedes aegypti*. The mosquitoes were under selection pressure for 45 consecutive generations against malathion. Resistance development rate was measured by LC$_{50}$ and LT$_{50}$ values. Adult females and larvae developed high resistance to malathion, having resistance ratio of 3.24 and 52.7 folds, respectively over control mosquitoes. Cross-resistance towards the same and different insecticidal groups was determined using the F44 and F45 malathion selected adult females. Results pointed out that the mosquitoes were highly resistant to fenitrothion and DDT, moderately resistant to propoxur, tolerant to cyhalothrin and permethrin, and very low resistant to cyfluthrin.

Khan et al., (2011) investigated the toxicity of representative agrochemicals against different populations of *Aedes albopictus* and noted moderate to high resistance level to agrochemicals in Pakistani field populations of this species. The geographic extent of resistance is not known but, if widespread, may lead to problems in future vector control programs.

Thipwara et al., (2011) assessed susceptibility to lambdacyhalothrin, deltamethrin and permethrin where a wide level of physiological response to permethrin was noticed in *Aedes aegypti*, ranging from 56.5% survival to only 4%. All 32 populations of *Aedes aegypti* were observed to have proof of developing resistance (62.5%) or levels of survival deemed resistant (37.5%) to permethrin. Four populations of *Aedes albopictus* were noticed with incipient resistance (97-80% mortality) and one with resistance to permethrin (< 80%). 68.7% of the *Aedes aegypti* populations was susceptible (> 98% mortality) to deltamethrin. They concluded that monitoring of
dengue mosquito vectors for usual and comprehensive susceptibility to synthetic parathyroid should be a required part of resistance management strategies and disease control activities.

Jahan and Amna, (2012) carried out study on larval bioassays with early 4th instars susceptible colony to find out diagnostic dose where a range of known concentrations (1.25, 2.5, 5, 10, 20, 40, and 100 ppm) of Bti WDG was used for a period of 60 minutes. The 10ppm dose was found post 30 min exposure whereas, in 60 min exposure, the same concentration caused 100% mortality of the field collected larvae. The resistance level was termed as resistance ratio (RR) of lethal time for 50% death caused in field collected and susceptible strain. The results pointed out that the field collected larvae were 10 folds more resistant than susceptible population with respect to dose, while RR LT50 - RR LT90 ranged 1.97-2.22 against Bti (WDG) in *Aedes aegypti* larvae.

Karen et al., (2012) examined the effect of rising larval rearing temperatures on the resistance status of Trinidadian populations of *Aedes aegypti* to organophosphatic insecticides. The majority of larval populations reared at 28±2°C were susceptible (≥98% mortality) to fenthion but resistant (<80% mortality) to malathion and temephos. Positive correlation was observed between resistance to organophosphatic insecticides and enhanced activities of larval populations reared at 28±2°C. Although the larvae reared at increased temperatures showed differences in resistance levels against organophosphates, a general increase in susceptibility was noticed.

### 2.4 Insect growth regulator

Hotakoshi et al., (1987) found a new synthesized juvenile hormone active compound, (2-[1-methyl-2-(4-phenoxyphenoxy) ethoxy] pyridine) which is more active than temephos, diflubenzuron and methoprene against last instar larvae of *Culex pipien pallens*, *Anopheles stephensi* and *Aedes aegypti*.

Trayler et al., (1994) revealed that juvenile hormone mimic pyriproxyfen at 0.01 ppm against late larval instars of *Chironomid polypedilum* caused 90% emergence inhibition of this species. In a field trial of pyriproxyfen at 0.01 ppm considerably
reduced *P. nubifer* emergence and another Chironomid, *Kiefferrulus intmincrus* (Skuse) for 24 days. Pyriproxyfen can act as satisfactory alternative to organophosphates.

Ali *et al.*, (1995) found IGRs, Pyriproxyfen (LC$_{90}$ = 0.000376 ppm) was 21.5 and 2.23 folds more toxic than methoprene and, diflubenzuron respectively. Generally, the toxicity ranking was: IGRs > parathyroid > OPs > microbials.

Lee, (2001) evaluated the granular formulation of 0.5% pyriproxyfen for emergence inhibition of *Aedes togoi* in brackish water of rock pools. Complete adult emergence inhibition in 4th-stage larval and pupal isolations was influenced from 5-40 days at 0.05 mg/L post treatment. Most rates of inhibition were over 80% throughout the examinations at all test concentrations of pyriproxyfen except 61.0% and 67.5% of inhibition rates at 0.01 mg/L at 52 days and 62 days post treatment, respectively. It was proposed that the dose for a good control of *Aedes togoi* for long-term might be 0.05-0.1 mg/L of 0.5% pyriproxyfen granules.

Nayar *et al.*, (2002) tested the residual activity and effectiveness of granular formulations of 2 Insect Growth Regulators (IGRs), pyriproxyfen and S-methoprene against laboratory-reared larvae of 5 colonized mosquitoes, *Culex nigripalpus*, *Anopheles quadrimaculatus*, *Aedes albopictus* and *Aedes aegypti* in the laboratory and outdoors in plastic tubs. Pyriproxyfen in comparison to S-methoprene caused very high levels (>80-100% in most cases) of initial and residual emergence inhibitions of the tested species in the laboratory as well as outdoors. In several species, pyriproxyfen induced complete adult emergence inhibition for several weeks post treatment, even at the lower rate of 0.02 ppm.

Sihuincha *et al.*, (2005) searched out pyriproxyfen against a local population of *Aedes aegypti*. Results showed that, when applied to late larval instars, pyriproxyfen prevented adult emergence at very low concentrations (LC$_{50}$=0.012 ppb). No adult emergence was observed from water sampled from storage tanks that had been seeded with the equivalent of 50-83 ppb (AI) pyriproxyfen. Even after five months, despite constant dilution of these tanks, water samples of these sources continued to be lethal to pupae and larvae.
Vythilingam, (2005) investigated the IGR, pyriproxyfen against *Aedes aegypti* at 0.01 and 0.02 mg of Active Ingredient (AI) per liter of water in 60-liter earthen jars. Both concentrations provided 100% control for four months. In additional experiments where 10 liters of water were replaced fortnightly, 100% control was still obtained over four months with 0.02 mg AI. Whereas, in less controlled field-trial conditions, pyriproxyfen at a dosage of 0.02 mg AI/liter provided 100% control for 10 wk against *Aedes albopictus* even though water was replaced either daily or weekly.

### 2.5 Botanical extracts

Tatiana *et al.*, (2005) assessed the biological activity of *Tanacetum parthenium* on *Leishmania amazonensis*. The crude extract had a 50% inhibitory concentration (LC$_{50}$) at 490µg/ml, whereas, the dichloromethane extract showed LC$_{50}$ of 3.6µg/ml after 48 hours exposure period.

Kumar and Maneemegalai, (2008) examined the mosquito larvicidal activity of ethanol and methanol leaves and flowers extracts of *Lantana camara* Linn. in a dose dependent manner against the 3rd and 4th instar larvae of mosquito species *Aedes aegypti* and *Culex quinquefasciatus*. Maximum mortality was observed in *Aedes aegypti* with 1.0 mg/ml concentration of extracts of *L. camara* exposed for 24 h. In the case of *Culex quinquefasciatus* the mortality was seen maximized when the concentration was increased to 3.0mg/ml.

Ahmad *et al.*, (2011) investigated *In-Vitro* larvicidal and anti-oxidant enzymes capability of the medicinal plants against *An. stephensi* 4$^{th}$ instar larval. The results indicated that *An. stephensi* had developed resistance against different insecticides. Efficacy of ethanol extracts (65-90%) was superior to the methanol extract (70-87%) and dichloromethane extract (60-70%). It was concluded that among the tested extracts, *Stevia rebaudiana* showed higher larvicidal activity with LC$_{50}$ (24 h) in methanol extract than *Parthenium hysterophorus* and *Ginkgo biloba* and *P. hysterophorous* exhibited the strongest anti-oxidative enzymes activity.

Kumar *et al.*, (2011) prepared various extracts of 1,000 ppm from the leaves of *Parthenium hysterophorus* using petroleum ether, benzene, acetone, hexane and diethyl ether as the solvents. The efficacy the extracts was tested against *Aedes aegypti* by
calculating the variations in fertility, behavioral response and fecundity of the female adults. The leaf extracts caused 70-100% repellency in the adult’s oviposition behavior. The diethyl ether extract was the most efficient resulting in maximum repellency (99.7%) giving the highest levels of decreased fecundity and 100% egg mortality followed by extracts of benzene which caused 100% ovicidal effect and 93.8% reduced oviposition. Hexane and acetone extracts gave least oviposition deterrence of 70-74% and negligible egg mortality (8-9%). The petroleum ether extract had a moderate impact causing 41% ovicidal effect and 93.2% reduced fecundity.

Mandal, (2011) evaluated the repellent activity of Eucalyptus and Azadirachta indica seed oils (using coconut oil base) against Culex quinquefasciatus mosquito. The test oils showed excellent repellent action against Culex quinquefasciatus. The A. indica seed oil provided 90.26% and 88.83% protection, and the Eucalyptus oil 93.37% and 92.04%, at concentrations 50% and 100% (v/v), respectively, with the protection time up to 240 min. There was no bite within 120 min and 180 min, respectively, due to the action of Eucalyptus and A. indica seed oil, and thus 100% protection from the bite of Culex quinquefasciatus mosquito was achieved.

Siriporn and Soonwera, (2011) reported that the essential oils of Cymbopogon citratus, C. nardus, Syzygium aromaticum, Ocimum basilicum and Cananga odorata gave strong effective dose values at <0.003 mg/cm² when tested against Culex quinquefasciatus. For testing by arm in cage method, at 0.21 mg/cm², protection time of C. citratus gave the longest lasting period against three mosquito species, 72 min for Aedes aegypti, 132 min for An. dirus and 84 min for Culex quinquefasciatus. In addition, the two essential oils exhibited moderate repellency against Aedes aegypti, An. dirus and Culex quinquefasciatus, at 60, 90 and 78 min with C. nardus, and 54, 96 and 72 min with S. aromaticum, respectively. The results showed that the percentage repellency increased when the concentration of essential oils increased. In contrast, biting rates decreased when the concentration of essential oils increased. C. citratus exhibited high efficiency for the protection time and the percentage of biting deterrent against all of 3 mosquito species.

Kumara et al., (2012) revealed that the different concentrations of crude extract of Sargassum wightii resulted in considerable mortality and the LC₅₀ value for first instar
larvae at 1.0 mg/l was 0.88, for 2nd instar 0.73, for 3rd Instar 1.34, for 4th instar 1.56, and for pupa 1.71. The LC90 values of (1-4th) instars and pupa were 2.73, 2.43, 3.03, 3.21, and 3.23 mg/ml, respectively. Among the larval instars, 2nd instar was the most susceptible. A considerable repellency (89%) was noted. Sea weed extract and B. thuringiensis toxins affected the larval duration and adult emergence. The result revealed that the sea weed extract of S. wightii in combination with microbial toxins has interfered in the gut system and resulted in mortality as well as growth inhibitory effects on mosquitoes.

Wasu et al., (2013) used locally available plant weeds Parthenium hysterophorus and Ageratina adenophora against polyphagus pest, Spodoptera frugiperda under laboratory conditions They found the LC50 value for methanol extract of P. hysterophorus and A. adenophora for 72 hours of exposure against fifth instar larvae were 5.92% & 7.82% and LC90 values were 8.14% & 8.96% respectively.

2.6 Sterile Insect Technique (SIT)

Benedict and Robinson, (2003) explained the SIT use as a safe techniques comprising of mass production, releases and subsequent mating competitiveness with wild females. The genetically modified mosquitoes have the potential of decreasing mosquito borne diseases transmission by releasing and establishing in the target sites.

Dyck et al., (2005) stated that SIT is an environment friendly and species specific method of insect control in which large numbers of sterile insects are released. This is a useful insect control method against a range of agricultural insect pest and pests of public health importance.

Michelle et al., (2006) defined the 3 stages of SIT, i.e. mass production, sterilization and subsequent release of sterile insects into a target population in an area-wide integrated approach. The released sterile males mate with wild females; they thus no longer produce offspring and therefore the size of the target population is decreased. SIT has been proven to be a safe, effective and environment friendly approach to suppress, remove or contain pest populations. The International Atomic
Energy Agency (IAEA) has a long history of supporting SIT programs against tsetse flies, moths and fruit flies.

Alphey et al., (2010) reported SIT as an effective tool of vector control. They proposed that SIT is more valuable in the integrated multi-approaches control strategies and SIT may be very efficient that dramatically reduce the number of insects when the target vector density is decreased by other methods. However, the cost and benefits of SIT should be always assessed before planning any strategy for the control of mosquito populations, in the light of the specific situation and local constrains.

Dumont and Chiroleu, (2010) integrated chemical and mechanical control with SIT for mosquitoes control. They found that integrated approach including SIT control could be useful to control the wild mosquito population and thus lowered the risk of an epidemic.

Boyer et al., (2011) evaluated the mating ability of a local strain of Aedes albopictus using several batches of females and different cage sizes under laboratory conditions. Individual males inseminated 14 females at an average of 9.5 females/male, they were exposed to 20 females for 7 days. The average number of females inseminated/male was 5.3 when two virgin females were exposed to one male and replaced every day for 12 consecutive days, and 8.6 when 10 virgin females were exposed to one male and replaced every day for 14 consecutive days. It was suggested that the high number of females inseminated by one male and the duration of male activity may have strong implications in SIT for mosquitoes.

Conclusions

The above mentioned literature shows that dengue is a widespread mosquito-borne disease in human beings, which has recently evolved into an imperative public health problem in Pakistan. Sewage water, irrigation channels, scarp materials and presence of fresh water in containers are the most important breeding sites of mosquitoes which may be eliminated or modified. The control of spreading in addition to biting of vector mosquito is the only effective way of dengue management (WHO, 2008). Ovitrap surveillance is a supportive tool in determining the occurrence,
population dynamics and to identify the key areas for the control of dengue vector species. The knowledge about the local vector habitat profiles, population dynamics, distribution trend and relative abundance, etc. are important for devising effective management strategies for the mosquito vectors. Also knowing the status of resistance level of the prevailing mosquito’s species to various groups of insecticides may help in devising improved management tools. The common attribute of all these studies so far reviewed suggest that the dengue problem need to be addressed by planning a sustainable long term management strategy with main emphasis on the environment friendly tactics; use of IGRs, phyto-chemicals and application of Sterile Insect Techniques (SIT) in an effective way.

1.2 Summary map on the status of dengue fever and dengue vectors in the world
III. MATERIALS AND METHODS

1 & 2: Entomological Surveillance for relative abundance in the key breeding sites of Peshawar Valley

Entomological surveys of mosquito species were conducted in Peshawar, Charsadda, Nowshera and Mardan districts of Khyber Pakhtunkhwa, Pakistan during 2011 and 2012. Larval, pupal and adults sampling from various sites were made according to the sampling methods of Suleman et al., (1993) and Hamidian, (2007).

Larval/pupal survey and collection

Various breeding sites; irrigation channels, pools, river banks, different containers inside houses and lawns and potential breeding places (water tanks, etc.) were monitored fortnightly. Larval and pupal collections were made with 0.5 liter standard iron dippers. The collected larvae were brought in plastic bottle (2 L) into laboratory and were reared following the rearing methods of Khan (2010). Identification to the species level was made with the help of available taxonomic keys (Khan, 1971; Marks, 1974; Knight and Stone, 1977; Maslov, 1989; Ralphe and Kitching, 1998; Rueda, 2004). Site index was calculated as: Number of positive sites/Total number of sites visited x 100. The index was used as criteria for the key habitats of the mosquito’s species. The larval abundance per site was calculated by dipping the dippers randomly five times by dividing the sites into four sub-sites and one middle portion. The mean number of larvae/pupae collected per dip was recorded after the five dips sampling for each habitat under study. Correlation studies were made for the species composition, population dynamics with the ecological factors (temperature, pH, turbidity, etc.).

Indoor/outdoor ovitraps surveillance of dengue vectors

Locally fabricated black color plastic ovitraps (25 x 37cm) (Khan et al., 2011) were used as monitoring tool for the Aedes and other mosquito’s species. The ovitraps were filled with 300 ml water and larval diet was added as attractant for the mosquito’s oviposition. Oviposition strips comprising of hard board (15 x 5 cm) having rough surface were placed in slanting position in each trap as medium for sitting and subsequent oviposition in the traps. All traps were placed in 15-20 different indoor (bathroom, bed room) and outdoor (lawn, veranda) of houses per selected sites randomly. All the ovitraps were examined and replaced after 10-15 days subject to
access to the study sites. The traps were brought back to the laboratory. The hard board strips were examined under microscope for mosquito’s egg laying. The water contents were poured into a plastic container from the ovitraps and were allowed to breed in the laboratory for next 7-10 days. The containers were kept covered. Small amount of NIFA mosquitoes larval diet comprising of 1:1 ratio of grains; wheat, bean, maize and bovine liver powder (Khan, 2010) was added into each container as larval food. The hatched larvae were subsequently counted and studied at 3rd instar under stereo microscope (Stereo-microscope, Optica, SZMA1, and Italy) for identification. The numbers of larvae were recorded individually for each positive ovitrap and the ovitrap index were calculated based on the number of positive trap per total of ovitraps recovered from the sites. The misplaced or emptied traps due to animal or human disturbance were ignored.

**Data analysis**

Data were analyzed using completely randomized design (CRD) replicated four times. Ovitrap Index (OI) was determined as the percent number of positive ovitraps to the total number of recovered ovitraps in each surveillance study. Mean number of *Aedes* spp. larvae per total number of recovered ovitraps were determined. All levels of statistical significance were determined at p < 0.05 using Fisher LSD-test. This study will lead into the basic entomological surveillance of the prevailing condition of the mosquito’s fauna in the area for further planning of the integrated management strategy.
1.3a Study sites for entomological surveillances in Peshawar
1.3b Study sites for entomological surveillances in Mardan
1.3c Study sites for entomological surveillances in Nowshera
3. **Status of insecticide susceptibility/resistance in field strains of *Aedes* and *Culex* spp.**

Larvae of mosquitoes collected from the selected sites under study were tested for their susceptibility to different groups of insecticides viz., chlorpyrifos, lambda-cyhalothrin, deltamethrin and temephos) that are used for vector control in the province. History of the pesticides usage or otherwise was taken into consideration while collecting the mosquitoes species from the sites. Collection and identification methods were same as described above in the insect rearing portion. Bioassay tests were made following standard techniques of World Health Organization with slight local modification as needed (WHO, 1970, 1981; Brogdon and Mcallister, 1998).

**Adult’s bioassays**

For testing the susceptibility of adult’s female’s mosquitoes to the tested chemicals, blotting paper was used as test media during the bioassays. Blank Ultra Low
Volume (ULV) spray of tap water was used as determining tool for calculating the volume of water on the target measured area of blotting paper. The required concentration for testing was optimized by series of tests starting from the lowest possible doses of the insecticides. The recommended doses were also kept into consideration during the trials. As testing media the WHO standard vials kits comprising of 2 units separated by movable net were replaced by simple plastic bottles designed in the same fashion for simplicity of the tests. The bottles were cut on the both sides and covered with nylon cloth after inserting the treated w/v or v/v paper at different concentrations of the chemicals under study. Proper care was taken during the handling of mosquitoes and keeping into trials in the locally designed kits for avoiding the escape during the experiment. Female’s mosquitoes (30) were selected for the tests by naked eyes observation based on the plumose/pilose status of antennae. The period of exposure was kept as 1, 24 and 48 hour for recording the mortality or otherwise condition of the test mosquito’s species.

**Larval bioassays**

Larval bioassays were made by applying the chemicals in the distilled water by w/v at the required concentration after series of test for optimizing the LC50 of the tested chemicals. Disposable plastic cups (500 ml) were used for the larval bioassays in replicated trials. The whole testes were repeated twice under similar laboratory conditions for maximizing the chances for precision and accuracy.

Data on the mortality were recorded as per exposure period and compared by using ANOVA. Polo plus Leora Software was used for plotting the dosage and mortality by log transformation. This data was used as criteria for the resistance or susceptibility level of the respective field strains of the mosquitoes from the selected sites.

**4 a. Efficacy of Insect Growth Regulars (IGRs) against Aedes and Culex spp.**

**Laboratory bioassays**

A laboratory colony of Culex and Aedes were established by collecting the larvae from the breeding habitats. The culture was established for both the species following the standard mosquitoes rearing procedures of Khan, 2010. Albino rats were provided as blood source to the adult females. The granular formulation of IGRs was ground to the uniformity of fine particles with a mortar and pestle and agitated
for 1 h in distill water. The IGRs were dissolved by W/V to make stock solution of 10mg/L (10ppm). This suspension was subjected in serial dilution and used to derive final concentrations of 0.01 to 0.05 ppm in tap water. The evaluations of IGRs were made following the methods of Mulla et al., 1974; Sihuincha et al., 2005 with slight modification according to our requirements. Bioassays experiments in the laboratory were conducted in CRD using different concentration (0.01, 0.02, 0.03, 0.04 and 0.05ppm) of juvenile hormones mimics i.e. methoprene, pyriproxyfen 1.0WDG and pyriproxyfen 0.5 WDG separately against 3rd instar of *Aedes* and *Culex spp.* Methoprene was purchased from the market in Annular grade. While 2 formulations of the pyriproxyfen was supplied by Evyol Chemicals group, Lahore, Pakistan for the trails. F1 generations of the larvae were used in the bioassays. Following the methods of Sihuincha (Sihuincha et al., 2005) all materials used for containing eggs, larvae, or adults over the course of the experiments were disposed of after each test for minimizing the potential contamination of experiments with minute doses of IGRs. Further care was taken by handling larvae, pupae, or adults using disposable plastic pipettes. The efficacy of IGRs were tested against the batches of 25 (3rd instar) larvae added to 500 ml disposable cups containing 100 ml of the above mentioned solutions and 0.01 g (3 drops) of 2% larval diet slurry. Controls consisted of simple tap water and food only. Each concentration and the control were represented by 4 replicates, and the entire assay was repeated two times. All cups were capped with gauze to prevent the escape of emerging adults and were monitored up to 15-21 days. Tests cups were examined daily, molted exoskeletons, dead larvae or pupae, and emerged adults were removed. A 12 hour photoperiod and 28± 2°C were maintained in the evaluation room during the tests.

**Efficacy of IGR’s under field conditions**

Three mosquito breeding sites of sizes 10.1 m$^3$, 12.53 m$^3$ and 11 m$^3$ for treatment with Pyriproxyfen 1.0WDG and 8 m$^3$ area for control at Kala Mandi were selected for these experiments. These sites were identified as having mix culture of mosquito’s species. The sites were treated using field rates recommended by Evyol chemical groups at the rates of 0.1 g/1 m$^3$ in 1000 liters of water. The approximate volume of water in the site was calculated by length (m) x width (m) x average depth (m) = cubic meter (m$^3$) water volume. IGR’s were applied in a pouch bag of muslin cloth in each replication, suspended in the body of the habitat by a building wire. Pretreatment and post treatment
observations were made fortnightly in each site and control. However, the data that was somewhat misleading was not utilized as criteria for the efficiency of the IGR rather each month, 5 liter samples of water from the treated site were collected and taken to the laboratory for testing the efficacy as described by Sihuincha et al., 2005. Here, cohorts of 25 laboratory colonized 3rd instar larvae of Aedes and Culex spp were added. These cohorts were compared with control pots containing 1 liter of uncontaminated tap water only. NIFA larval diet solutions (1%) were added to all pots as a food source. Percent larval mortality, adult emergence inhibition, deformities, adult emergence were recorded for a period (1-6 months) after the treatment. For statistical comparison, data were arcsine transformed and subjected to ANOVA using Fisher LSD test.

**Statistical analysis**

Data on mortality, inhibition and deformity was pooled for dose response analysis by probit (using the probit analysis package Polo Plus, Leora Software, Berkeley, CA). The cumulative toxicity was determined at the termination of the tests when all the biological parameters were completed in the control by calculating LC50 and LC90 through the said software. The percent inhibition of adult emergence of the species in each treatments was adjusted for any larval or pupal mortalities in corresponding controls with the formula of Mulla (Mulla et al., 1974): % inhibition of emergence = 100 - 100(T/C), where T is percent emergence in treated containers and C is percent emergence in control containers. Mean percent larval mortality, deformities and reductions of adult emergence, in each batch of mosquito species caused by the formulations of IGRs were analyzed by 2 way analysis of variance through Fisher LSD test (Steel and Torrie, 1980).

**4 b. Evaluation of larvicidal properties of different botanical extracts**

The larvicidal potential of Stevia rebaudiana, Parthenium hyterophrus, Chrysanthemum morifolium, Neem (Azadirachta indica) extract and oil was compared with the commercial larvicides (Temophos) against Aedes albopictus and Culex quinquefasciatus larvae. There were four replications per treatment.

**Preparation of plant extracts**

The plant species under investigation were collected from field or local market. The sweet plant (Stevia spp.) was obtained from the Biotechnology group, NIFA,
Peshawar. The leaves of the plants were shade dried \( (28\pm2^\circ C) \) and ground mechanically using commercial electrical stainless steel blender and sieved to get fine powder from which the extract was prepared following the method of Khan et al. (2012). Water extract of the plant species was taken as 250 g of dried leaf powder in a separate container. With this 1250 ml of distilled water was added and kept for 16 hours with periodic shaking, and the filtrate of extract was collected. The pooled extracts were concentrated separately by rotary vacuum evaporator at 40°C under reduced pressure of 22-26 mm of Hg and evaporated to dryness and stored at 4°C in air-tight bottles. The extract obtained from each plant was dissolved independently to get 20% stock solutions, which was diluted to lower concentrations of 0.5, 1, 2, 3 and 5% with tap water.

**Dose-Response Larvicidal Bioassays**

Mosquito’s larvicidal trials were carried out as per WHO (2005) standard procedure with slight modifications following the method by Rahuman et al. (2008c). From the stock solution different concentrations were prepared \( (0.5, 1, 2, 3, 4 \text{ and } 5 \%) \) for testing their larvicidal efficiency. Twenty five third instar larvae of *Aedes* and *Culex* were selected and transferred into cups of prepared test solution. NIFA food was added to the larvae. The numbers of dead larvae were counted after 24 and 48 hours of exposure. Percent mortality was recorded from the average of four replications. However, at the end of 24 and 48 hours the selected test samples that were turned out in their toxic potential to equal to temephos (standard check) were selected. The percent mortality was corrected by the formula of Abbott (1925) by using simple tap water as natural check. The data recorded were subjected to ANOVA and significant means were separated by using Fisher protected LSD test for mean separations (Steel and Torrie, 1980).

Comparative toxicity of plant crude extracts against 3rd-4th instars *Aedes albopictus* and *Culex quinquefasciatus* for 24 and 48 hrs exposure periods was calculated by using Polo plus software, Leora Berkeley, CA using range of LC50/LC90 as standard.
5. Assessment of irradiation doses for sterility of vectors mosquito and subsequent mating compatibility with wild females.

Mosquitoes were differentiated and separated into males and females based on sexual dimorphism at the pupal stage. Conical flask was used initially for the separation of the pupae from the mix culture of the larval tubs. Care was taken to select the pupae of the same age. Then the male and female pupae were separated by using density principle, i.e. female pupae are large in size and thus denser which remained in the bottom of the flask as compared to the male pupae. The male pupae present on the surface of the container were effectively transferred using the standard mesh sieve mechanically. One thousand male pupae were separated in short period of 5 minutes. Ten transparent plastic bottle having 100 male pupae each was exposed to different radiation doses i.e. 20, 40, 60, 80 and 100 Gy by Cobalt 60 irradiation source at NIFA, Peshawar. Each radiation dose was tested against the 4 sets comprising 100 pupae in the trials. The effect of each dose was worked out by recording the percent adult emergence and testing their sterility by conducting the mating ability and subsequent progeny production ability. Deformities in the adults were also recorded as a result of the tested radiation doses. During male competitiveness test harmless dye was used for identification of sterile males and the wild females during the compatibility trials following Khan et al., 2012.
IV. RESULTS

4.1 Entomological surveillance of mosquito during 2011-2012

Experiments on entomological surveillance of *Culex*, *Aedes* and *Anopheles* mosquito species were carried out at different locations of Peshawar, Nowshera, Mardan and Charsadda districts of Khyber Pakhtunkhwa, Pakistan during 2011-2012. The data collected on monthly mosquito larval abundance from different habitats is presented in tables 4.1.1 to 4.1.12.

*Culex* species (*Culex* spp.) larval abundance showed significant variations at different locations of Peshawar (Table 4.1.1). Mean monthly abundance of larvae was highest (731) at Ring Road collected from sewage water, followed by Tarnab Colony where, 718 larvae were collected from sewage water. The lowest density of larvae (9) was found at NIFA-II collected from discarded scrap materials and bird drinking containers. Low number of larvae (11) was also noted at Tahkal-II from used tires. The results revealed that Culex larvae inhabited sewage water at Ring Road, Tarnab Colony, Kala Mandi-I and Hayatabad-I. Minimum larval number (47 and 54) was recorded during December and January, respectively. Maximum larvae (1011) of *Culex* spp. were recorded during September. Positively highly significant correlation for *Culex* spp. was observed (Table 4.1.14) with temperature ($\gamma$=0.670) and turbidity ($\gamma$=0.864), non-significant with pH ($\gamma$ =0.445), while negatively highly significant correlation was recorded with dissolved oxygen ($\gamma$=0.815). The monthly index (Fig. 4.1.1) results indicated that larval hatching started in January, increased in subsequent months and reached to its peak number during September, afterwards decrease occurred till December.

The results related monthly abundance of *Aedes* spp collected from different locations and their habitat types at Peshawar is presented in Table 4.1.2. Significant differences were observed in *Aedes* spp. abundance among different locations. Mean monthly population of larvae was highest (38) at NIFA-I collected from irrigation channels, while lowest population (2) was noted at Muslim Town-I collected from mixture of sewage and irrigation water. No larvae were found at Tarnab Colony, Kala Mandi-I, Ring Road, Hayatabad-I, Bakhshupul, Bus Stop, Tahkal-I and Tahkal-II. According to the monthly index mean maximum larval density was recorded during
September to December where the population was 13.9, 18.6, 35.2 and 10.9, respectively. The abundance of *Aedes* spp. was low from January to July with mean density of 2.4, 2.1, 2.9, 3.1, 3.3, 2.6 and 1.8, respectively (Fig. 4.1.2). Negative value of highly significant correlation was observed for *Aedes* spp. (Table 4.1.13) with temperature ($\gamma = -0.662$), significant with turbidity ($\gamma = -0.595$) and non-significant with pH ($\gamma = -0.279$), while positively significant correlation was recorded with dissolved oxygen ($\gamma = 0.525$). The results indicated that larval density was low in January increased up to May, decreased during June-July, increased again in August and declined subsequently till December.

Mean monthly abundance of Anopheles species (*An.* spp.) collected from different sites and habitat types in Peshawar is presented in Table 4.1.3. Significant differences were found among the different sites and habitat types. Mean monthly abundance of larvae was highest (13) at Kala Mandi-II collected from irrigation water, while lowest density of larvae (6) was noted at University of Agriculture, Peshawar collected from pots vases. Beside this no larvae were found in all sites except NIFA-II and Tarnab Farm where mean larvae were 10 and 12 collected from irrigation channels. Mean maximum larval density (Fig.4.1.3) recorded during August, September and October was 4.3, 8.7 and 4.5, respectively. The population of *An.* spp. was low from January to July and December where the mean density was 1.1, 1.6, 1.7, 2.3, 2.8, 0.5, 1.1 and 0.2, respectively. Negative value of non-significant correlation for *An.* spp. was observed (Table 4.1.13) with temperature ($\gamma = -0.482$) and turbidity ($\gamma = -0.431$), while positively non-significant correlation was recorded with pH ($\gamma = 0.044$) and dissolved oxygen ($\gamma = 0.492$). The results revealed that larval abundance started in January increased up to May and decreased during June-July but further increased in August, September and decreased during October till December.

The immature abundance of *Culex* spp. showed significant variations collected from various sites in a range of habitat types at Nowshera (Table 4.1.4). Mean abundance of larvae was highest (237) at Pabbi-II collected from sewage water, while it was lowest (5) at Pabbi-I collected from used tires. It is also evident from the results that *Culex* larvae were found in sewage water at Taru-I, Pabbi-II and Nowshera Kalan. Minimum larval population (15 and 11) was recorded during December and January, respectively, while maximum larvae (310) of *Culex* spp. were recorded during
September. Positively highly significant correlation for *Culex* spp. was observed (Table 4.1.14) with pH ($\gamma=0.866$) and turbidity ($\gamma=0.903$), non-significant with temperature ($\gamma=0.596$), while negatively highly significant correlation was recorded with dissolved oxygen ($\gamma=-0.750$). Larval hatching started in January increased till May, decreased during June-July, increased again and reached to its peak in September and later on declined till December.

Results regarding monthly abundance of *Aedes* spp. collected from different places in choice of habitat types at Nowshera are presented in Table 4.1.5. Significant differences were observed among monthly abundance of *Aedes* spp. at different locations. Mean monthly abundance of larvae was highest (31) at new Military Dairy Farm Khaishk collected from irrigation channels, while lowest density of larvae (2) was noted at Taru-I collected from sewage water. No larvae were found at Pabbi-II, Nowshera Kalan, Mian Kalay and Kabul River. Mean maximum abundance was recorded during October and November where the population was 23 and 29, respectively. The abundance of *Aedes* spp. was low from January to July with mean density of 2.4, 3.4, 4.7, 3.9, 5.1, 1.8 and 1.3 larvae from January to July, respectively. *Aedes* spp. (Table 4.1.13) was negatively non-significantly correlated with temperature ($\gamma=-0.467$), pH ($\gamma=-0.396$) and turbidity ($\gamma=-0.528$), while positively significantly correlated with dissolved oxygen ($\gamma=0.155$). The results indicated that larval hatching started in January increased up to May, decreased during June-July, increased again from August till November, and declined in December.

Mean monthly abundance of *An.* spp. in Nowshera collected from different sites and habitat types are presented in Table 4.1.6. There were found significant differences in *An.* spp. abundance among the various sites and habitat types. The mean abundance of larvae was highest (9) at Taru-I collected from irrigation water, while lowest abundance of larvae (5) was noted at Kabul River collected from ponds and flood water. It is evident from the results that no *An.* spp. larvae were found at Taru-II, Azakhel-I, Pabbi-I, Pabbi-II, Nowshera Kalan and Mian Kalay. Mean maximum larval abundance (11) was recorded during October. The population of *An.* spp. was low from January to July and December with 0.5, 0.8, 2.0, 2.5, 2.8, 1.6, 1.2 and 0.4 larvae, respectively. *An.* spp. (Table 4.1.13) was negatively non-significantly correlated with temperature ($\gamma=-0.428$), pH ($\gamma=-0.087$) and dissolved oxygen ($\gamma=-0.259$), while positively non-significantly
correlated with turbidity ($\gamma = 0.053$). The results revealed that larval hatching started in January, increased up to May, decreased during June-July, increased again in August-September and decreased again from October till December.

The larval abundance of *Culex* spp. showed significant variations collected from various sites in a range of habitat types at Mardan (Table 4.1.7). Mean larval abundance was highest (270) at Locomotive Factory Residential Colony (LFRC) collected from sewage water, while lowest abundance of larvae (19) was noted at College Chowk-II collected from used tires. It is clear from the results that LFRC, College Chowk-I, Toru and Rahimabad were the inhabited areas where Culex larvae were found in sewage water, irrigation channels and scrap material. Minimum larval abundance (16 and 15) was recorded during December and January, respectively. Maximum larvae (361) of *Culex* spp. were recorded during September. Positively non-significant correlation for *Culex* spp. was observed (Table 4.1.14) with temperature ($\gamma = 0.359$), pH ($\gamma = 0.009$) and turbidity ($\gamma = 0.595$), while negatively non-significant correlation was recorded with dissolved oxygen ($\gamma = -0.615$). The results showed that larval hatching started in January, increased up to May, decreased during June-July, reached to its peak during September and declined till December.

The results of monthly abundance of *Aedes* spp. collected from different places in choice of habitat types at Mardan are presented in Table 4.1.8. There were found significant differences in *Aedes* spp. population among the different sites. The insect abundance was highest (90) at Toru collected from scrap materials, while it was lowest (13) at Takhtbhai collected from sewage water mixed with fresh irrigation water in channels. No *Aedes* spp. larvae were found at SCRI-I, LFRC, College Chowk-I and College Chowk-II. Mean maximum larval abundance of 81 larvae was recorded during November. The abundance of *Aedes* spp. was low from January to July with mean density of 4, 6, 9, 16, 11, 9 and 7, respectively. Negatively non-significant correlation for *Aedes* spp. was observed (Table 4.1.14) with temperature ($\gamma = -417$) and pH ($\gamma = -0.088$), while positively non-significant correlation was recorded with dissolved oxygen ($\gamma = 0.045$) and turbidity ($\gamma = 0.073$). The results indicated that larval hatching started in January, increased up to April, decreased during May-July, increased again from August till November and declined in December.
The results of monthly abundance of *An.* spp. in Mardan collected from different sites and habitat types are presented in Table 4.1.9. It is evident from the results that abundance of *An.* spp. varied among the various sites. The mean abundance of larvae was highest (10.3 larvae) at Rahimabad collected from irrigation channels. Larval population was lowest (7.9 larvae) at SCRI-II collected from irrigation channels mixed with sewage water. No *An.* spp. larvae were recorded at SCRI-I, Toru, Locomotive Factory residential colony, College Chowk-I and College Chowk-II. Mean maximum larval density (17) was recorded during September. The abundance of *An.* spp. was low from January to July and December where the mean density was 0.5, 3, 3, 3.2, 4, 2, 2.5 and 2 larvae, respectively. Negatively significant correlation for *An.* spp. was observed with temperature ($\gamma = -0.752$), highly significant with turbidity ($\gamma = -0.771$), while positively significant correlation was recorded (Table 4.1.14) with dissolved oxygen ($\gamma = 0.677$) and non-significant with pH ($\gamma = 0.395$). Larval hatching started in January, increased up to May, reached to its peak in September and decreased during October till December.

The *Culex* spp. abundance showed significant variation collected from various sites in a range of habitat types at Charsadda (Table 4.1.10). Mean abundance of larvae was highest (240 larvae) at Rajar collected from sewage water and Sardaryab (239 larvae) collected from pool/ponds water. The lowest abundance of larvae (8 larvae) was noted at Charsadda-I collected from used tires. Minimum larval abundance of 27 and 15 larvae was recorded during December and January, respectively. Maximum larvae (515) of *Culex* spp. were recorded during September. *Culex* spp was negatively non-significantly correlated (Table 4.1.14) with temperature ($\gamma = -0.025$) and dissolved oxygen ($\gamma = -0.136$), while positively non-significantly correlated with pH ($\gamma = 0.210$) and turbidity ($\gamma = 0.012$). Larval hatching started in January, increased in May, decreased during June-July, reached to its peak during September and declined during October till December.

There were found significant variations in monthly abundance of *Aedes* spp. collected from different places in choice of habitat types at Charsadda (Table 4.1.11). Mean abundance of larvae was highest (27 larvae) at Naguman and Sardaryab (26 larvae), collected from ponds and pools of river water. The lowest abundance of eight larvae was recorded at Shabara and Charsadda-I collected from flood water and used
tires. No larvae were recorded at Rajar and Charsadda-II. Mean maximum larval abundance was recorded during October and November with 30 and 35 larvae, respectively. The abundance of *Aedes* spp. was low from January to July where the mean abundance of 4, 5, 7, 10, 11, 3 and 3 was found from January to July, respectively. *Aedes* spp. was negatively non-significantly correlated (Table 4.1.13) with temperature ($\gamma = -0.695$), significantly with pH ($\gamma = -0.766$) and turbidity ($\gamma = -0.791$), while positively significantly correlated with dissolved oxygen ($\gamma = 0.806$). It is evident from the results that larval hatching started in January, increased up to May, decreased during June-July, increased again from August till November and declined in December.

Mean monthly abundance of *An.* spp. in Charsadda collected from different sites and habitat types showed significant differences (Table 4.1.12). The mean abundance of larvae was highest (50 larvae) at Naguman collected from ponds and pools, while lowest (2 larvae) at Shabara collected from flood water with temporary nature of water reserves. No *An.* spp. larvae were recorded at Rajar, Charsadda-I and Charsadda-II. Mean maximum larval abundance (64 larvae) was found during September. The abundance of *An.* spp. was low from January to July and December where the mean density was 3, 3, 4, 6, 7, 3, 1 and 3 larvae, respectively. *An.* spp. (Table 4.1.14) was negatively non-significantly correlated with temperature ($\gamma =-0.497$), pH ($\gamma =-0.532$) and turbidity ($\gamma =-0.579$), while positively non-significantly correlated with dissolved oxygen ($\gamma =0.577$). Larval hatching started in January, increased up to May, decreased during June-July, increased again from August till September and declined again from October till December.

The overall abundance of *Culex*, *Aedes* and *Anopheles* collected from various locations showed significant differences (Table 4.1.13). Highest abundance of specimen (5300) was found in sewage water, followed by ponds (813) and irrigation channels (497). *Culex* spp. were at peak stage of 3600, 641, 697 and 328 larvae collected from sewage water found in Peshawar, Nowshera, Mardan and Charsadda, respectively, (Fig.4.1.4a). The abundance of *Culex spp.* (3871, 899, 972, 827 larvae), *Aedes spp.* (137, 102, 224, 91 larvae) and *An.* spp. (41, 37, 47, 101 larvae) was found in Peshawar, Nowshera, Mardan and Charsadda, respectively (Fig.4.1.4b). The results showed that higher number of *Culex spp.* larvae collected from sewage water was found in the vicinity of Peshawar.
Table 4.1.1 Mean monthly larval/pupal abundance of *Culex* spp. in various habitats at Peshawar during 2011-2012

<table>
<thead>
<tr>
<th>Site</th>
<th>Hbaitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>NIFA-I</td>
<td>I.C.</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>NIFA-II</td>
<td>Scrap</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M.Town-I</td>
<td>S.W.</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>M.Town-II</td>
<td>Tanks</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Tarnab Cly</td>
<td>S.W.</td>
<td>198</td>
<td>288</td>
</tr>
<tr>
<td>Tarnab Farm</td>
<td>I.C.</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Kala M-I</td>
<td>S.W.</td>
<td>167</td>
<td>234</td>
</tr>
<tr>
<td>Kala M-II</td>
<td>I.W.</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>Ring road</td>
<td>S.W.</td>
<td>143</td>
<td>208</td>
</tr>
<tr>
<td>Hyt-abd-I</td>
<td>S.W.</td>
<td>121</td>
<td>186</td>
</tr>
<tr>
<td>Hyt-abd-II</td>
<td>P.V.</td>
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<td>0</td>
</tr>
<tr>
<td>Agri.Univ</td>
<td>P.V.</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Bakhsupul</td>
<td>S.W.</td>
<td>88</td>
<td>139</td>
</tr>
<tr>
<td>Bus stop</td>
<td>Tires</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Tahkal-I</td>
<td>S.W.</td>
<td>39</td>
<td>45</td>
</tr>
<tr>
<td>Tahkal-II</td>
<td>Tires</td>
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<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>54^a</td>
<td>76^f</td>
</tr>
</tbody>
</table>

Standard Deviation = 553.16  Standard Error = 23.05
LSD value at 0.05% for types = 5.26  LSD value at 0.05% for months= 4.56
Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
I.C. = Irrigation channels  S.W. = Sewage water  I.W. = Irrigation water  P.V. = Pots vase
Table 4.1.2 Mean monthly larval/pupal abundance of *Aedes* spp. in various habitats at Peshawar during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>2</td>
</tr>
<tr>
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<td>I.C.</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>NIFA-II</td>
<td>Scrap</td>
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<td>9</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M.Town-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M.Town-II</td>
<td>Tanks</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamab Cly</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tamab Farm</td>
<td>I.C.</td>
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<td>9</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Kala M-I</td>
<td>S.W.</td>
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<td>0</td>
</tr>
<tr>
<td>Kala M-II</td>
<td>I.W.</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ring road</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hyt-abd-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hyt-abd-II</td>
<td>P.V.</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agri.Univ</td>
<td>P.V.</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bakhsupul</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bus stop</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tahkal-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tahkal-II</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>2.4</td>
<td>2.1</td>
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</table>

Standard Deviation = 23.33  
Standard Error = 0.97

LSD value at 0.05% for types = 0.30  
LSD value at 0.05% for months= 0.26

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

I.C. = Irrigation channels  
S.W. = Sewage water  
I.W. = Irrigation water  
P.V. = Pots vase
Table 4.1.3 Mean monthly larval/pupal abundance of *Anopheles* spp. in various habitats at Peshawar during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>NIFA-I</td>
<td>I.C.</td>
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<td>5</td>
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<tr>
<td>NIFA-II</td>
<td>Scrap</td>
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<td>0</td>
</tr>
<tr>
<td>M.Town-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M.Town-II</td>
<td>Tanks</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Tarnab Colony</td>
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<td>0</td>
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<tr>
<td>Kala M-I</td>
<td>S.W.</td>
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<td>0</td>
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<tr>
<td>Kala M-II</td>
<td>I.W.</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Ring road</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hyt-abd-I</td>
<td>S.W.</td>
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<td>0</td>
</tr>
<tr>
<td>Hyt-abd-II</td>
<td>C.W.</td>
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<td>0</td>
</tr>
<tr>
<td>Agri.Univ</td>
<td>P.V.</td>
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<td>0</td>
</tr>
<tr>
<td>Bakhsupul</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bus stop</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tahkal-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tahkal-II</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.1 i</td>
<td>1.6 h</td>
</tr>
</tbody>
</table>

Standard Deviation = 6.89 Standard Error = 0.29

LSD value at 0.05% for types = 0.19
LSD value at 0.05% for months = 0.17

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

I.C. = Irrigation channels  S.W. = Sewage water  I.W. = Irrigation water  P.V. = Pots vase
Fig. 4.1.1 Monthly Index of *Culex* spp. in Peshawar during 2011-2012

Fig. 4.1.2 Monthly Index of *Aedes* spp. in Peshawar during 2011-2012.
Fig. 4.1.3 Monthly index of *Anopheles* spp. in Peshawar during 2011-2012.
Table 4.1.4. Mean monthly larval/pupal abundance of *Culex* spp. in various habitats at Nowshera during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Taru-I</td>
<td>S.W.</td>
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<td>Scrap</td>
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<td>Azakhel-I</td>
<td>F.P.</td>
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<td>Azakhel-II</td>
<td>I.C.</td>
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<td>Pabbi-I</td>
<td>Tires</td>
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<td>0</td>
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<tr>
<td>Pabbi-II</td>
<td>S.W.</td>
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<td>24</td>
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<td>Nowshera Kalan</td>
<td>Ponds</td>
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<td>17</td>
</tr>
<tr>
<td>Old military dairy farm</td>
<td>Tanks</td>
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<td>0</td>
</tr>
<tr>
<td>New military dairy farm</td>
<td>I.C.</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Mian kalay</td>
<td>S.W.</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>Kabul river</td>
<td>Ponds</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>11&lt;sup&gt;k&lt;/sup&gt;</td>
<td>14&lt;sup&gt;i&lt;/sup&gt;</td>
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</table>

Standard Deviation = 178.56  Standard Error = 8.97

LSD value at 0.05% for types = 0.71  LSD value at 0.05% for months = 0.74

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

S.W. = Sewage water,  F.P. = Flower pots,  I.C. = Irrigation channel
Table 4.1.5. Mean monthly larval/pupal abundance of *Aedes* spp. in various habitats at Nowshera during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Taru-I</td>
<td>S.W.</td>
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<td>0</td>
</tr>
<tr>
<td>Taru-II</td>
<td>Scrap</td>
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<td>5</td>
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<tr>
<td>Azakhel-I</td>
<td>F.P.</td>
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<td>4</td>
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<tr>
<td>Azakhel-II</td>
<td>I.C.</td>
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<tr>
<td>Pabbi-I</td>
<td>Tires</td>
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<td>5</td>
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<tr>
<td>Pabbi-II</td>
<td>S.W.</td>
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<td>0</td>
</tr>
<tr>
<td>Nowshera–K</td>
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<td>0</td>
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<td>Old military</td>
<td>Tanks</td>
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<td>14</td>
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<tr>
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<td>8</td>
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<tr>
<td>farm</td>
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<tr>
<td>Mian kalay</td>
<td>S.W.</td>
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<td>0</td>
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<tr>
<td>Kabul river</td>
<td>Ponds</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>2.4^i</td>
<td>3.4^h</td>
</tr>
</tbody>
</table>

Standard Deviation = 16.83     Standard Error = 0.85
LSD value at 0.05% for types = 0.37     LSD value at 0.05% for months= 0.38
Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
S.W. = Sewage water,     F.P. = Flower pots,     I.C. = Irrigation channel
Table 4.1.6. Mean monthly larval/pupal abundance of *Anopheles* spp. in various habitats at Nowshera during 2011-12.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Taru-I</td>
<td>I.C.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Taru-II</td>
<td>Scrap.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Azakhel-I</td>
<td>F.P.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Azakhel-II</td>
<td>I.C.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pabbi-I</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pabbi-II</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nowshera Kalan</td>
<td>Ponds</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Old military dairy farm</td>
<td>Tanks</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>New military dairy farm</td>
<td>I.C.</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Mian kalay</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kabul river</td>
<td>Ponds</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Standard Deviation = 6.22    Standard Error = 0.31

LSD value at 0.05% for types = 0.25    LSD value at 0.05% for months= 0.27

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

S.W. = Sewage water,    F.P. = Flower pots,    I.C. = Irrigation channel
Fig. 4.1.4 Monthly Index of *Culex* spp. in Nowshera during 2011-2012

Fig. 4.1.5  Monthly Index of *Aedes* spp. in Nowshera during 2011-2012.
Fig. 4.1.6 Monthly index of *Anopheles* spp. in Nowshera during 2011-2012.
Table 4.1.7. Mean monthly larval/pupal abundance of *Culex* spp. in various habitats at Mardan during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
</tr>
<tr>
<td>SCRI-I</td>
<td>S.W.</td>
<td>15 17 22 24 104 35 26 67 289 275 86 14</td>
<td>81e</td>
</tr>
<tr>
<td>SCRI-II</td>
<td>I.C.</td>
<td>7 8 13 15 24 18 9 29 56 34 19</td>
<td>4 20f</td>
</tr>
<tr>
<td>Jalala</td>
<td>S.W.</td>
<td>10 11 24 29 43 22 20 68 209 187 17 8</td>
<td>54g</td>
</tr>
<tr>
<td>Toru</td>
<td>Scrap</td>
<td>16 23 34 46 86 45 30 128 306 265 85 11</td>
<td>90d</td>
</tr>
<tr>
<td>Nigar bagh</td>
<td>Ponds</td>
<td>0 5 21 25 37 20 18 58 219 106 47 8</td>
<td>47h</td>
</tr>
<tr>
<td>Rahimabad</td>
<td>I.C.</td>
<td>13 18 22 36 86 38 40 155 307 298 12 2</td>
<td>54 99c</td>
</tr>
<tr>
<td>Takhtbhai</td>
<td>S.W.</td>
<td>11 16 18 25 77 33 24 111 202 128 38 9</td>
<td>58f</td>
</tr>
<tr>
<td>Loco-Cly</td>
<td>S.W.</td>
<td>37 41 44 61 301 210 112 403 1018 926 52 31</td>
<td>270a</td>
</tr>
<tr>
<td>College C-I</td>
<td>S.W.</td>
<td>37 41 46 48 311 89 68 328 928 825 56 26</td>
<td>234b</td>
</tr>
<tr>
<td>College C-II</td>
<td>Tires</td>
<td>0 0 11 15 38 18 15 21 75 28 12 0</td>
<td>19i</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>15k 18i 25b 32g 111d 53e 36f 137c 361a 307b 53e 16j</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard Deviation = 176.61  
Standard Error = 9.31

LSD value at 0.05% for types = 0.86  
LSD value at 0.05% for months = 0.94

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).  
S.W. = Sewage water,  
I.C. = Irrigation channel
Table 4.1.8. Mean monthly larval/pupal abundance of *Aedes* spp. in various habitats at Mardan during 2011-12.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>SCRI-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCRI-II</td>
<td>I.C.</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Jalala</td>
<td>I.W.</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Toru</td>
<td>Scrap</td>
<td>16</td>
<td>23</td>
</tr>
<tr>
<td>Nigar bagh</td>
<td>Ponds</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Rahimabad</td>
<td>I.C.</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Takhtbhai</td>
<td>S.W.</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Loco-Cly</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>College C-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>College C-II</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Standard Deviation = 49.06  Standard Error = 2.59

LSD value at 0.05% for types = 0.40  LSD value at 0.05% for months= 0.44
Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
S.W. = Sewage water,  I.C. = Irrigation channel  I.W. = Irrigation water tank
Table 4.1.9. Mean monthly larval/pupal abundance of *Anopheles* spp in various habitats at Mardan during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>SCRI-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SCRI-II</td>
<td>S.W.</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Jalala</td>
<td>IC/SW</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Toru</td>
<td>Scrap</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nigar bagh</td>
<td>Ponds/IL</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Rahimabad</td>
<td>I.C.</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Takhthbai</td>
<td>S.W.</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Loco-Cly</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>College C-I</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>College C-II</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.5</td>
<td>3</td>
</tr>
</tbody>
</table>

Standard Deviation = 7.93

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

S.W. = Sewage water,  I.C. = Irrigation channel  I.L. = Irrigation leakage
Fig. 4.1.7 Monthly Index of *Culex* spp. in Mardan during 2011-2012

Fig. 4.1.8 Monthly Index of *Aedes* spp. in Mardan during 2011-2012.
Fig. 4.1.9 Monthly index of *Anopheles* spp. in Mardan during 2011-2012.
Table 4.1.10  Mean monthly larval/pupal abundance of Culex spp in various habitats at Charsadda during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Naguman</td>
<td>Ponds</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Sardaryab</td>
<td>Pools</td>
<td>25</td>
<td>37</td>
</tr>
<tr>
<td>Rajar</td>
<td>S.W.</td>
<td>33</td>
<td>27</td>
</tr>
<tr>
<td>Shabara</td>
<td>F.W.</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Malkadher</td>
<td>I.C.</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Charsada-I</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Charsada-II</td>
<td>S.W.</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>15</td>
<td>18</td>
</tr>
</tbody>
</table>

Standard Deviation = 231.13
Standard Error = 14.56
LSD value at 0.05% for types = 0.86
LSD value at 0.05% for months= 1.12

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
S.W. = Sewage water, I.C. = Irrigation channel, F.W. = Flood water
Table 4.1.11. Mean monthly larval/pupal abundance of *Aedes* spp in various habitats at Charsadda during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Naguman</td>
<td>Ponds</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Sadaryab-I</td>
<td>Pools</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Rajar</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shabara</td>
<td>F.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Malkadher</td>
<td>I.C.</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Charsada-I</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Charsada-II</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>4&lt;sup&gt;f&lt;/sup&gt;</td>
<td>5&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard Deviation = 17.31  
Standard Error = 1.09

LSD value at 0.05% for types = 0.37  
LSD value at 0.05% for months = 0.49

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

S.W. = Sewage water,  
I.C. = Irrigation channel,  
F.W. = Flood water
Table 4.1.12. Mean monthly larval/pupal abundance of *Anopheles* spp. in various habitats at Charsadda during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat Type</th>
<th>Month (January-December)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Naguman</td>
<td>Ponds</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Sadaryab-I</td>
<td>Pools</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Rajar</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shabara</td>
<td>F.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Malkadher</td>
<td>I.C.</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Charsada-I</td>
<td>Tires</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Charsada-II</td>
<td>S.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard Deviation = 39.51      Standard Error = 2.49

LSD value at 0.05% for types = 0.36    LSD value at 0.05% for months= 0.47

Mean in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

S.W. = Sewage water,    I.C. = Irrigation channel,    F.W. = Flood water
Fig. 4.1.10 Monthly Index of *Culex* spp. in Charsadda during 2011-2012

Fig. 4.1.11 Monthly Index of *Aedes* spp. in Charsadda during 2011-2012.
Fig. 4.1.12 Monthly index of *Anopheles* spp. in Charsadda during 2011-2012.
Table 4.1.13. Mean larval/pupal abundance of different species collected from different habitat types at various locations during 2011-2012.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Location</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peshawar</td>
<td>Nowshera</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>Ae</td>
</tr>
<tr>
<td>I.C.</td>
<td>95</td>
<td>50</td>
</tr>
<tr>
<td>I.W.</td>
<td>39</td>
<td>9</td>
</tr>
<tr>
<td>S.W.</td>
<td>3600</td>
<td>2</td>
</tr>
<tr>
<td>Scrap</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>Tanks.</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Tires</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Pot vaste</td>
<td>63</td>
<td>26</td>
</tr>
<tr>
<td>Ponds</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pools</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F.P.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F.W.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>3871</td>
<td>137</td>
</tr>
</tbody>
</table>

I.C. = Irrigation channel, I.W. = Irrigation water, S.W. = Sewage water
F.P. = Flower pots, F.W. = Flood water
Fig. 4.1.4a Mean population index of mosquitoes collected from various habitat types during 2011-2012

Fig. 4.1.4b Mean population index of mosquito species collected from various locations during 2011-2012.
Table 4.1.14. Species correlation with physico-chemical conditions of mosquitoes at different locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
<th>Temp.</th>
<th>pH</th>
<th>Dissolved oxygen</th>
<th>Turbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peshawar</td>
<td>Culex</td>
<td>0.670**</td>
<td>0.445ns</td>
<td>-0.815**</td>
<td>0.864**</td>
</tr>
<tr>
<td></td>
<td>Aedes</td>
<td>-0.662**</td>
<td>-0.279ns</td>
<td>0.525*</td>
<td>-0.595*</td>
</tr>
<tr>
<td></td>
<td>Anopheles</td>
<td>-0.482ns</td>
<td>0.044ns</td>
<td>0.492ns</td>
<td>-0.431ns</td>
</tr>
<tr>
<td>Nowshera</td>
<td>Culex</td>
<td>0.596ns</td>
<td>0.866**</td>
<td>-0.750**</td>
<td>0.903**</td>
</tr>
<tr>
<td></td>
<td>Aedes</td>
<td>-0.467ns</td>
<td>-0.396ns</td>
<td>0.155ns</td>
<td>-0.528ns</td>
</tr>
<tr>
<td></td>
<td>Anopheles</td>
<td>-0.428ns</td>
<td>-0.087ns</td>
<td>-0.259ns</td>
<td>0.053ns</td>
</tr>
<tr>
<td>Mardan</td>
<td>Culex</td>
<td>0.359ns</td>
<td>0.009ns</td>
<td>-0.615ns</td>
<td>0.595ns</td>
</tr>
<tr>
<td></td>
<td>Aedes</td>
<td>-0.417ns</td>
<td>-0.088ns</td>
<td>0.045ns</td>
<td>0.073ns</td>
</tr>
<tr>
<td></td>
<td>Anopheles</td>
<td>-0.752*</td>
<td>0.395ns</td>
<td>0.677*</td>
<td>-0.771**</td>
</tr>
<tr>
<td>Charsadda</td>
<td>Culex</td>
<td>-0.025ns</td>
<td>0.210ns</td>
<td>-0.136ns</td>
<td>0.012ns</td>
</tr>
<tr>
<td></td>
<td>Aedes</td>
<td>-0.695ns</td>
<td>-0.766*</td>
<td>0.806*</td>
<td>-0.791*</td>
</tr>
<tr>
<td></td>
<td>Anopheles</td>
<td>-0.497ns</td>
<td>-0.532ns</td>
<td>0.577ns</td>
<td>-0.579ns</td>
</tr>
</tbody>
</table>

* Significantly different,  ** Highly significantly different,  ns Non-significantly different
4.2 Indoor/outdoor ovitraps surveillance of mosquito species during 2011-2012

Results of mosquito species indoor/outdoor ovitraps surveillance during 2011-2012 is presented in tables 4.2.1 to 4.2.8. The results were significantly different for the mosquito species (Table 4.2.1). Culex species (Fig. 4.2.1 to 4.2.3) dominated Aedes and Anopheles. Mean monthly positive ovitraps of Culex was high (9.38%) at indoor sites in Peshawar. The mean proliferation of indoor Aedes was only 0.40%, which started in November and December. Culex and Anopheles peaked in September (13.5%) and October (10.0%), respectively. The activities of both species started in January, increased up to May, decreased during June-July. It increased again in August-September and decreased afterwards till December. Activities of Culex and Anopheles were high during September and October, while of Aedes in November-December.

The results of mosquito’s species surveillance were significantly different at indoor locations at Nowshera (Table 4.2.2). Culex spp. (10.4%) dominated Aedes and Anopheles (Fig. 4.2.1 to 4.2.3). But the mean abundance of Aedes remained much lower (0.51%) in November and December. Activities of Culex and Anopheles peaked in September (13.2%). The activities of both species started at January (0.67%), increased up to May (9.67%), decreased during June-July (3%, 2%), increased again in August-September and declined till December. It is evident from the results that Culex and Anopheles were self-motivated species during September and October, while Aedes became visible in November-December.

In Mardan the results of surveillance of mosquito species complex at indoor locations were significantly different (Table 4.2.3). Culex spp. dominated (16.5%) the other two species at different indoor sites in Mardan (Fig. 4.2.1 to 4.2.3). Mean abundance of Aedes decreased to 0.22% in November and December. Culex and Anopheles peaked in September (13.7%). Activities of Culex started in January (2.83%) and of Anopheles started in April (7.5%), increased up to May (11.4%), decreased during June-July (3.83%, 2.28%), increased again in August-September and declined to minimum till December. Culex and Anopheles were active till August-September but afterwards its activities were slowly decreased till complete inactivity in December.

Various species of mosquitoes showed significant variations in abundance collected from different indoor sites in Charsadda (Table 4.2.4). Culex spp. (10.6%)
dominated the other two species (Fig. 4.2.1 to 4.2.3). Mean minimum abundance of *Aedes* was 0.36% in November and December. Culex and *Anopheles* peaked in August (9.33%), September (15.1%) and October (9.56%). The activities of Culex and Anopheles started in January (1.05%), increased up to May (9.78%), decreased during June-July (3.44%, 1.72%), increased again during August-September and decreased to minimum till December. *Culex* and *Anopheles* were high in number during August-September but afterwards decreased continuously till December.

In Peshawar mosquito species abundance significantly differed at various locations (Table 4.2.5). *Culex* (32.3%) dominated the other two species at outdoor sites in Peshawar (Fig. 4.2.4 to 4.2.6). The three species peaked in May (32.5%) and October (31.5%). The activities of species complex started at January, increased till May, decreased during June-July. It increased again from August to October but declined to minimum till December. Generally, all the three species were active from May and October.

The mosquito species differed in abundance at outdoor locations at Nowshera (Table 4.2.6). *Aedes* (19.3%) and *Culex* (18.8%) species dominated *Anopheles* (3.69%) (Fig. 4.2.4 to 4.2.6). The three species peaked in October (26.8%). The activities of the three species started in January (1.95%), increased till May (25.3%). It decreased during June-July (8.05%, 4.43%) but increased again in August to October. The activities of the three species reached to its minimum in December. Generally, activities of the three species were more from May till October.

In Mardan, the mosquito species significantly differed in abundance at various outdoor locations (Table 4.2.7). *Culex* spp. (20.3%) dominated the other two species (Fig. 4.2.4 to 4.2.6). The *Anopheles* population remained much lower (2.62%) from April to December. The three species peaked in May with a mean of 22.2%. The activities of the three species started at January (2.83%), increased till May (22.2%) and decreased afterwards during June-July (6.06%, 3.44%). It increased again in August-September and then declined continuously till December.

The mosquito species abundance differed significantly at the various outdoor sites in Charsadda (Table 4.2.8), where *Culex* spp. had the highest number (21.0%) than
other two species (Fig. 4.2.4 to 4.2.6). Mean abundance of *Anopheles* remained much lower (7.83%) from January to December. The mean abundance of all the three species (*Culex*, *Aedes* and *Anopheles*) was at peak stage in May (27.0%), September (27.0%) and October (26.9%). Activities of the three species started at January (2.5%), increased till May (27.0%) and then decreased afterwards during June-July (5.0%, 2.9%). It increased again from August to October but declined to minimum till December. Generally, activities of the three species were maximum from May to October and minimum in December.

Overall, the outdoor ovitrap index was significantly higher and alarming than the indoor ovitrap index for all the mosquitoes groups trapped during the study and remained alarming due to high percentage (>32%) than the minimum permissible standard index of 5%.
Table 4.2.1. Indoor ovitraps index of mosquito species in Peshawar during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>0.67i</td>
<td>0.78i</td>
</tr>
</tbody>
</table>

Standard deviation = 6.37 Standard error = 0.61
LSD value at 0.05% for species = 0.27; LSD value at 0.05% for months = 0.54
Means in last column and last row followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

Table 4.2.2. Indoor ovitraps index of mosquito species in Nowshera during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>2</td>
<td>3.9</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>0.67a</td>
<td>1.29j</td>
</tr>
</tbody>
</table>

Standard deviation = 6.61 Standard error = 0.64
LSD value at 0.05% for species = 0.22; LSD value at 0.05% for months = 0.43
Means in last column and last row followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.2.3. Indoor ovitraps index of mosquito species in Mardan during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>8.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>2.83(^f)</td>
<td>3.17(^f)</td>
</tr>
</tbody>
</table>

Standard deviation = 8.94 Standard error = 0.86
LSD value at 0.05% for species = 0.26; LSD value at 0.05% for months = 0.53
Means in last column and last row followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

Table 4.2.4. Indoor ovitraps index of mosquito species inCharsadda during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>2.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>1.05(^g)</td>
<td>1.78(^f)</td>
</tr>
</tbody>
</table>

Standard deviation = 6.96 Standard error = 0.67
LSD value at 0.05% for species = 0.36; LSD value at 0.05% for months = 0.71
Means in last column and last row followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Fig. 4.2.1 Indoor ovitraps index of *Culex* spp. at different sites during 2011-2012.

Fig. 4.2.2 Indoor ovitraps index of *Aedes* spp. at different sites during 2011-2012.
Fig. 4.2.3 Indoor ovitraps index of *Anopheles* spp. at different sites during 2011-2012.
Table 4.2.5. Outdoor ovitraps index of mosquito species in Peshawar during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>9.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>Overall</td>
<td>3.11a</td>
<td>3.89a</td>
</tr>
</tbody>
</table>

Standard deviation = 17.59  Standard error = 1.69
LSD value at 0.05% for species = 0.57; LSD value at 0.05% for months = 1.13
Means in last column and last row followed by similar letters are not significantly different at 0.05% level of probability (LSD test).

Table 4.2.6. Outdoor ovitraps index of mosquito species in Nowshera during 2011 - 2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>3.3</td>
<td>5.9</td>
</tr>
<tr>
<td>Aedes</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Overall</td>
<td>1.95d</td>
<td>2.86a</td>
</tr>
</tbody>
</table>

Standard deviation = 13.84  Standard error = 1.33
LSD value at 0.05% for species = 0.40; LSD value at 0.05% for months = 0.80
Means in last column and last row followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.2.7. Outdoor ovitraps index of mosquito species in Mardan during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>8.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0.17</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>2.83\textsuperscript{h}</td>
<td>3.33\textsuperscript{h}</td>
</tr>
</tbody>
</table>

Standard deviation = 11.88  Standard error = 1.14
LSD value at 0.05\% for species = 0.41; LSD value at 0.05\% for months = 0.81
Means in last column and last row followed by similar letters are not significantly different at 0.05\% level of probability (LSD test).

Table 4.2.8. Outdoor ovitraps index of mosquito species in Charsadda during 2011-2012.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month (January-December)</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Culex</td>
<td>6.7</td>
<td>8.3</td>
</tr>
<tr>
<td>Aedes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anopheles</td>
<td>0.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>2.5\textsuperscript{b}</td>
<td>3.3\textsuperscript{b}</td>
</tr>
</tbody>
</table>

Standard deviation = 12.97  Standard error = 1.25
LSD value at 0.05\% for species = 0.57; LSD value at 0.05\% for months = 1.13
Means in last column and last row followed by similar letters are not significantly different at 0.05\% level of probability (LSD test).
Fig. 4.2.4 Outdoor ovitraps index of *Culex* spp. at different sites during 2011-2012.

Fig. 4.2.5 Outdoor ovitraps index of *Aedes* spp. at different sites during 2011-2012.
Fig. 4.2.6 Outdoor ovitraps index of *Anopheles* spp. at different sites during 2011-2012.
List of mosquito’s species found during the entomological surveillance in Peshawar valley during 2011-2012.

1. *Culex* species.
   • *Culex quinquefasciatus* Say
   • *Culex theileri* Theobald
   • *Culex tritaeniorhynchus* Giles
   • *Culex univittatus* Theobald
   • *Culex vishnui* Theobald

2. *Anopheles* species.
   • *Anopheles annularis* van der Wulp
   • *Anopheles culicifacies* Giles
   • *Anopheles maculates* Theobald
   • *Anopheles stephensi* Liston
   • *Anopheles subpictus* Grassi
   • *Anopheles superpictus* Grassi

3. *Aedes* species
   • *Aedes albopictus* (Skuse)

4. Predatory mosquitoes.
   • *Toxorhynchites*
   • *Corethrella*
4.3 Resistance in mosquito species against different insecticides

The results of insecticide susceptibility/resistance in field collected strains of *Culex* spp. and *Aedes* spp. were compared with laboratory reared susceptible strain and presented in tables 4.3.1 to 4.3.8. The results showed that Chlorpyrifos had significantly different effect on *Culex* spp. adult females (Table 4.3.1). *Culex* spp. mortality was significantly higher in control (55.83%) than all the treatments after one hour of treatment. Among the treatments significantly higher mortalities in *Culex* spp. adult females was recorded in the field strains of Sardaryab (47.50%) and lowest at Tarnab Colony (10.00%). After 24h of treatment, mortality of the *Culex* spp. adult females was 100% in control followed by Sardaryab (93.33%) and Azakhel Park (92.50%). Lowest mortality of the insect was observed in the females collected from Tarnab Colony (30.00%). Chlorpyrifos yielded 100% mortalities after 48h in the females in control and collected from Sardaryab and Azakhel Park. Lowest mortality was recorded at Tarnab Colony (50%). Overall mean mortality of *Culex* spp. adult females was highest in control (85.28%), which was followed by Sardaryab (80.28%) and Azakhel Park (79.72%). Lowest mortality of the insect was observed in the females collected from Tarnab Colony (30.00%). Mortality of the females increased from 28.15 to 79.54% with increase in exposure time from 01 to 48h.

Lambdacyhalothrin applied against *Culex* spp. adult females gave variable results (Table 4.3.2). After one hour of treatment, mortality of the *Culex* spp. females was significantly higher in control (62.50%) than all the treatments. Among the treatments significantly higher mortalities in *Culex* spp. adult females were recorded at Sardaryab (58.33%) and lowest at Taru Jabba (20.00%). After 24h of treatment, mortality of the adult females was 100% in control, which was followed by Sardaryab (95.00%) as well as Azakhel Park (95.00%). Lowest mortality of the insect was observed in the females collected from Tarnab Colony (42.50%). Lambdacyhalothrin yielded 100% mortalities after 48h in the females in control as well as collected from Sardaryab and Azakhel Park. Lowest mortality was recorded at Tarnab Colony (56.67%). Overall mean mortality of *Culex* spp. adult females was highest in control (87.50%), which was followed by in Sardaryab (84.44%) and Azakhel Park (82.78%). Lowest mortality of the insect was recorded in the females collected at Tarnab Colony (41.95%). Mortality of the females increased from 40.83 to 85.19% with increase in exposure time from 01 to 48h.
Deltamethrin showed variable mortalities in *Culex* spp. adult females after one, 24 and 48 hours of treatment (Table 4.3.3). After one hour of treatment, mortality of the *Culex* spp. females was significantly higher in control (57.50%) as well as in Sardaryab (57.50%). Lowest mortality of the insect was recorded in females collected from Tarnab Colony (16.67%). After 24h of treatment, mortality of the adult females was 100% in control, Sardaryab and Azakhel Park. It was lowest in females collected from Tarnab Colony (42.50%). Deltamethrin yielded 100% mortalities in females collected from Hayatabad, Azakhel Park, SCRI, College Chowk, Sardaryab, Rajar and in control. Lowest mortality was recorded at Tarnab Colony (58.33%). Overall mean mortality of *Culex* spp. adult females was significantly higher in females collected from Azakhel Park (86.11%) followed by Sardaryab (85.83%) and in control (85.83%). Lowest mortality of the insect was recorded in the females collected at Tarnab Colony (39.17%). With increase in exposure time from 01 to 48 hours, mortality of the females increased from 46.11 to 91.20%.

The results of efficacy of Temephos against field collected and lab reared *Culex* spp. larvae are given in (Table 4.3.4). After one hour of treatment, mortality of the *Culex* spp. larvae was significantly higher in control (65.00%) as well as in field strain collected from Sardaryab (63.33%). Lowest mortality of the insect was recorded in larvae collected from Hayatabad (33.33%). After 24h of treatment, mortality was 100 in larvae collected from Sardaryab as well as in control. It was lowest in larvae collected from Hayatabad (53.33%). After 48h of treatment, Temephos treatment gave 100% mortalities in larvae collected from Azakhel Park, SCRI, College Chowk, Sardaryab, Rajar and in control. Lowest mortality was recorded at Tarnab Colony (68.33%). Overall mean mortality of *Culex* spp. larvae was significantly higher in collection from Sardaryab (87.78%) and in control (88.33%). Lowest mortality of the insect was found in the larvae collected at Taru Jabba (50.00%). With the increase in exposure time from 01 to 48h mortality of the larvae increased from 45.19 to 92.11%

Application of Chlorpyrifos against field collected and lab reared *Aedes* spp. adult females yielded variable mortalities (Table 4.3.5). After one hour of treatment, mortality of the *Aedes* spp. females was significantly higher in control (59.17%) as well as in females collected from Azakhel Park (53.33%) and Naguman (52.50%). Lowest mortality of the insect was recorded in females collected from NIFA (30.00%). After
24h and 48h of treatment, mortality was 100 in females collected from Military Farm Khaishk, Azakhel Park, Naguman as well as in control. It was lowest in females collected from NIFA with 45.83% and 60.00%, respectively. Overall mean mortality of *Aedes spp.* adult females was significantly higher in females collected from Military Farm Khaishk (83.33%), Azakhel Park (84.44%), Naguman (84.17%) and in control (86.39%). Lowest overall mean mortality of the insect was found in the females collected at NIFA (45.28%). With the increase in exposure time from 01 to 48h mortality of the females increased from 44.91 to 86.48%.

Lambdacyhalothrin treatment against field collected and lab reared *Aedes* spp. adult females yielded significantly variable mortalities (Table 4.3.6). After one hour of treatment, mortality of the *Aedes* spp. females was significantly higher in control (59.17%) as well as in females collected from Military Farm Khaishk (56.67%), Azakhel Park (55.83%) and Naguman (55.83%). Lowest mortality of the insect was recorded in females collected from SCRI (36.67%). After 24h and 48h of treatment, mortality was 100 in females collected from Military Farm Khaishk, Azakhel Park, Naguman as well as in control. It was lowest in females collected from Malakadher with 65.00% and 82.50%, respectively. Overall mean mortality of *Aedes spp.* adult females was significantly higher in females collected from Military Farm Khaishk (85.56%), Azakhel Park (85.28%), Naguman (85.28%) and in control (86.39%). Lowest overall mean mortality of the insect was found in the females collected at Toru (61.11%). Overall mean mortality of the insect increased from 49.26% to 93.70% with the increase in exposure time from 01 to 48h.

Field collected and laboratory reared *Aedes* spp. adult females treatment with deltamethrin resulted in significantly variable mortalities (Table 4.3.7). After one hour of treatment, mortality of the *Aedes* spp. females was significantly higher in females collected from Hayatabad (63.33%), Azakhel Park (60.00%) and in control (59.17%). Lowest mortality of the insect was recorded in females collected from Toru (36.67%). After 24h and 48h of treatment, mortality was 100 in females collected from Hayatabad, Military Farm Khaishk, Azakhel Park, Naguman as well as in control. It was lowest in females collected from Toru (45.83%) after 24h and NIFA (77.50%) after 48h. Overall mean mortality of *Aedes spp.* adult females was significantly higher in females collected from Hayatabad (87.78%), Azakhel Park (86.67%) and in control (86.39%). Lowest
overall mean mortality of the insect was found in the females collected at NIFA (56.11%). Overall mean mortality of the insect increased from 50.65% to 92.31% with the increase in insecticide exposure time from 01 to 48h.

Temephos treatment of the field collected and laboratory reared *Aedes* spp. larvae resulted in significantly variable mortalities (Table 4.3.8). After one hour of treatment, mortality of the *Aedes* spp. females was significantly higher in larvae collected from Naguman (64.17%) and in control (66.67%). Lowest mortality of the insect was recorded in larvae collected from SCRI (37.50%). After 24h and 48h of treatment, mortality was 100 in larvae collected from Military Farm Khaishk, Azakhel Park, SCRI, Toru, Naguman, Malakadher as well as in control. It was lowest in females collected from NIFA after 24h (56.67%) as well as after 48h (82.50%). Overall mean mortality was significantly higher in *Aedes* spp. adult larvae collected from Naguman (88.06%) and in control (89.89%). Lowest overall mean mortality was found in the larvae collected at NIFA (61.94%). Overall mean mortality of the larvae increased from 50.93% to 97.31% with the increase in insecticide exposure time from 01 to 48h.
Table 4.3.1 Efficacy of chlorpyrifos against *Culex* spp. adult females collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Tarnab Colony</td>
<td>10.00&lt;sup&gt;j&lt;/sup&gt;</td>
<td>30.00&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>16.67&lt;sup&gt;i&lt;/sup&gt;</td>
<td>46.67&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Taru Jabba</td>
<td>16.67&lt;sup&gt;i&lt;/sup&gt;</td>
<td>50.83&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>46.67&lt;sup&gt;f&lt;/sup&gt;</td>
<td>92.50&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SCRI</td>
<td>19.17&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>52.50&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>College Chowk</td>
<td>24.17&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>49.17&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sardaryab</td>
<td>47.50&lt;sup&gt;f&lt;/sup&gt;</td>
<td>93.33&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rajar</td>
<td>16.67&lt;sup&gt;i&lt;/sup&gt;</td>
<td>50.83&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>55.83&lt;sup&gt;e&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>28.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>62.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 29.17  Standard error = 2.81

LSD value at 0.05% for site = 3.57;  LSD value at 0.05% for duration = 2.06;
LSD value at 0.05% for interaction = 6.18

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.2  Efficacy of lambdacyhalothrin against *Culex* spp. adult females collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Tarnab Colony</td>
<td>26.67&lt;sup&gt;e&lt;/sup&gt;</td>
<td>42.50&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>33.33&lt;sup&gt;j&lt;/sup&gt;</td>
<td>53.33&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Taru Jabba</td>
<td>20.00&lt;sup&gt;l&lt;/sup&gt;</td>
<td>54.17&lt;sup&gt;g,h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>53.33&lt;sup&gt;h&lt;/sup&gt;</td>
<td>95.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SCRI</td>
<td>29.17&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>55.00&lt;sup&gt;g,h&lt;/sup&gt;</td>
</tr>
<tr>
<td>College Chowk</td>
<td>54.17&lt;sup&gt;g,h&lt;/sup&gt;</td>
<td>83.33&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sardaryab</td>
<td>58.33&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>95.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rajar</td>
<td>30.00&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>57.50&lt;sup&gt;g,h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>62.50&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>40.83&lt;sup&gt;e&lt;/sup&gt;</td>
<td>70.65&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation  = 25.61  Standard error  = 2.46
LSD value at 0.05% for site  = 2.78  LSD value at 0.05% for duration  = 1.61
LSD value at 0.05% for interaction  = 4.82

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.3 Efficacy of deltamethrin against *Culex* spp. adult females collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Tarnab Colony</td>
<td>16.67(^g)</td>
<td>42.50(^i)</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>51.67(^g)</td>
<td>88.33(^d)</td>
</tr>
<tr>
<td>Taru Jabba</td>
<td>19.17(^j)</td>
<td>48.33(^h)</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>58.33(^f)</td>
<td>100.0(^a)</td>
</tr>
<tr>
<td>SCRI</td>
<td>54.17(^g)</td>
<td>95.83(^b)</td>
</tr>
<tr>
<td>College Chowk</td>
<td>51.67(^g)</td>
<td>91.67(^c)</td>
</tr>
<tr>
<td>Sardaryab</td>
<td>57.50(^f)</td>
<td>100.0(^a)</td>
</tr>
<tr>
<td>Rajar</td>
<td>48.33(^h)</td>
<td>54.17(^g)</td>
</tr>
<tr>
<td>Control</td>
<td>57.50(^f)</td>
<td>100.0(^a)</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>46.11(^c)</td>
<td>80.09(^b)</td>
</tr>
</tbody>
</table>

Standard deviation = 26.90  Standard error = 2.59
LSD value at 0.05% for site = 1.90  LSD value at 0.05% for duration = 1.10
LSD value at 0.05% for interaction = 3.29

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.4 Efficacy of temephos against *Culex* spp. larvae collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Tarnab Colony</td>
<td>45.00^f</td>
<td>56.67^e</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>33.33^g</td>
<td>53.33^e</td>
</tr>
<tr>
<td>Taru Jabba</td>
<td>20.00^h</td>
<td>54.17^e</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>53.33^e</td>
<td>95.00^a</td>
</tr>
<tr>
<td>SCRI</td>
<td>29.17^g</td>
<td>55.00^e</td>
</tr>
<tr>
<td>College Chowk</td>
<td>54.17^e</td>
<td>83.33^b</td>
</tr>
<tr>
<td>Sardaryab</td>
<td>63.33^d</td>
<td>100.0^a</td>
</tr>
<tr>
<td>Rajar</td>
<td>43.33^f</td>
<td>75.00^c</td>
</tr>
<tr>
<td>Control</td>
<td>65.00^d</td>
<td>100.0^a</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>45.19^c</td>
<td>74.72^b</td>
</tr>
</tbody>
</table>

Standard deviation = 25.13  
Standard error = 2.42

LSD value at 0.05% for site = 3.71  
LSD value at 0.05% for duration = 2.14  
LSD value at 0.05% for interaction = 6.42

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.5. Efficacy of chlorpyrifos against *Aedes* spp. adult females collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Pakistan Atomic Energy Commission</td>
<td>30.00&lt;sup&gt;th&lt;/sup&gt;</td>
<td>45.83&lt;sup&gt;jk&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>42.50&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>65.00&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>Military Farm Khaishk</td>
<td>50.00&lt;sup&gt;jl&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>53.33&lt;sup&gt;ghi&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SCRI</td>
<td>36.67&lt;sup&gt;l&lt;/sup&gt;</td>
<td>58.33&lt;sup&gt;fgh&lt;/sup&gt;</td>
</tr>
<tr>
<td>Toru</td>
<td>38.33&lt;sup&gt;l&lt;/sup&gt;</td>
<td>50.83&lt;sup&gt;ji&lt;/sup&gt;</td>
</tr>
<tr>
<td>Naguman</td>
<td>52.50&lt;sup&gt;hhi&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Malakadher</td>
<td>41.67&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>63.33&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>59.17&lt;sup&gt;efg&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>44.91&lt;sup&gt;c&lt;/sup&gt;</td>
<td>75.93&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 24.23  Standard error = 2.33
LSD value at 0.05% for site = 3.45  LSD value at 0.05% for duration = 1.99
LSD value at 0.05% for interaction = 5.97

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.6  Efficacy of lambdacyhalothrin against *Aedes* spp. adult females collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hrs</td>
</tr>
<tr>
<td>NIFA</td>
<td>40.00^ji</td>
<td>62.50^dec</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>49.17^g</td>
<td>79.17^c</td>
</tr>
<tr>
<td>Military Farm Khaishk</td>
<td>56.67^f</td>
<td>100.0^a</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>55.83^f</td>
<td>100.0^a</td>
</tr>
<tr>
<td>SCRI</td>
<td>36.67^j</td>
<td>62.50^dec</td>
</tr>
<tr>
<td>Toru</td>
<td>43.33^hi</td>
<td>50.83^g</td>
</tr>
<tr>
<td>Naguman</td>
<td>55.83^f</td>
<td>100.0^a</td>
</tr>
<tr>
<td>Malakadher</td>
<td>46.67^gh</td>
<td>65.00^d</td>
</tr>
<tr>
<td>Control</td>
<td>59.17^ef</td>
<td>100.0^a</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>49.26^c</td>
<td>80.00^b</td>
</tr>
</tbody>
</table>

Standard deviation = 22.61  
Standard error = 2.18

LSD value at 0.05% for site = 2.52  
LSD value at 0.05% for duration = 1.45  
LSD value at 0.05% for interaction = 4.36

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.7  Efficacy of deltamethrin against *Aedes* spp. adult females collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after 01 hr</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakistan Atomic Energy Commission</td>
<td>33.33&lt;sup&gt;1&lt;/sup&gt;</td>
<td>57.50&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>77.50&lt;sup&gt;d&lt;/sup&gt;</td>
<td>56.11&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>63.33&lt;sup&gt;e&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>87.78&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Military Farm Khaishk</td>
<td>55.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>85.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>60.00&lt;sup&gt;efg&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>86.67&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>SCRI</td>
<td>50.00&lt;sup&gt;i&lt;/sup&gt;</td>
<td>59.17&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>82.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>63.89&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Toru</td>
<td>36.67&lt;sup&gt;1&lt;/sup&gt;</td>
<td>45.83&lt;sup&gt;j&lt;/sup&gt;</td>
<td>88.33&lt;sup&gt;b&lt;/sup&gt;</td>
<td>56.94&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Naguman</td>
<td>56.67&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>85.56&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Malakadher</td>
<td>41.67&lt;sup&gt;k&lt;/sup&gt;</td>
<td>60.83&lt;sup&gt;er&lt;/sup&gt;</td>
<td>82.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>61.67&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>59.17&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>86.39&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>50.65&lt;sup&gt;c&lt;/sup&gt;</td>
<td>80.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 23.34  
Standard error = 2.25  
LSD value at 0.05% for site = 2.11  
LSD value at 0.05% for duration = 1.22  
LSD value at 0.05% for interaction = 3.65  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.3.8 Efficacy of temephos against *Aedes* spp. larvae collected from different field sites during 2011-2012.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mortality (%) after</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01 hr</td>
<td>24 hs</td>
</tr>
<tr>
<td>Pakistan Atomic Energy Commission</td>
<td>46.67h</td>
<td>56.67f</td>
</tr>
<tr>
<td>Hayatabad</td>
<td>42.50i</td>
<td>61.67e</td>
</tr>
<tr>
<td>Military Farm Khaishk</td>
<td>50.83g</td>
<td>100.0a</td>
</tr>
<tr>
<td>Azakhel Park</td>
<td>54.17fg</td>
<td>100.0a</td>
</tr>
<tr>
<td>SCRI</td>
<td>37.50l</td>
<td>100.0a</td>
</tr>
<tr>
<td>Toru</td>
<td>50.83g</td>
<td>100.0a</td>
</tr>
<tr>
<td>Naguman</td>
<td>64.17de</td>
<td>100.0a</td>
</tr>
<tr>
<td>Malakadher</td>
<td>45.00hi</td>
<td>100.0a</td>
</tr>
<tr>
<td>Control</td>
<td>66.67d</td>
<td>100.0a</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>50.93c</td>
<td>90.93b</td>
</tr>
</tbody>
</table>

Standard deviation = 23.81 Standard error = 2.29
LSD value at 0.05% for site = 2.28 LSD value at 0.05% for duration = 1.31
LSD value at 0.05% for interaction = 3.94

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
4.4 Efficacy of Insect growth regulator (IGR) against *Aedes* and *Culex* Spp.

The results of the efficacy of Insect Growth Regulators (IGRs) Methoprene and different formulations of Pyriproxyfen (pyriproxyfen 1.0WDG and pyriproxyfen 0.5WDG) against different instars of *Culex* spp. are presented in tables 4.4.1 to 4.4.8. Different concentrations (0.01 to 0.05 ppm) of Methoprene had significant effect on growth inhibition and other biological parameters of *Culex* spp. larvae (Table 4.4.1). Twenty one days after Methoprene treatment at 0.01 ppm caused 40% inhibition and 24% adult emergence, whereas no inhibition (0%) and 91% adult emergence was observed in control. Mortality (%) increased with the application of Methoprene and it ranged from 7 to 40%. The highest concentration of 0.05 ppm showed 40% mortality after 21 days after treatment as compared to control (7%). Percent inhibition decreased from 40% (0.01 ppm) to 14% with the increase in Methoprene concentration. With increase in concentration of Methoprene from 0.01 to 0.05 ppm increase in the deformed population of mosquitoes from 23% to 37% occurred. Highest malformation of mosquitoes (37%) was recorded with 0.05 ppm concentration as compared to 2% in control. Adult emergence decreased from 24 to 9% with increase in Methoprene concentration (0.01 to 0.05 ppm). Generally, Methoprene concentrations of 0.01 to 0.05 ppm yielded mean mortality (20.7%), inhibition (28%), deformity (25.5%) and adult emergence (26.83%) in mosquito developmental stages.

Various concentrations (0.01 to 0.05 ppm) of Pyriproxyfen 0.5WDG resulted in significant differences in *Culex* spp. emergence and inhibition (Table 4.4.2). With the increase in Pyriproxyfen 0.5WDG concentration mortality increased from 10% to 67%. Pyriproxyfen 0.5WDG treatment at 0.05 ppm caused 67% mortality after 21 days whereas 0.01 ppm yielded 10% mortality. Lower concentration of 0.01 ppm resulted in 54% inhibition while 22% inhibition occurred with the higher concentration of 0.05 ppm. With the increase in Pyriproxyfen 0.5WDG concentration from 0.01 to 0.05 ppm, deformity in the mosquitoes decreased from 22% to 11%. In the control only 2% deformities were recorded. Generally, various concentrations (0.01 to 0.05 ppm) of Pyriproxyfen 0.5WDG caused mean mortality of 31.2%, inhibition of 35.7%, deformity of 13.7% and adult emergence of 18%.
The results of the effect of Pyriproxyfen 1.0WDG applied at different concentrations against *Culex* spp. are shown in Table 4.4.3. Significant differences were observed in appearance and different biological parameters of mosquitoes treated with various concentrations of Pyriproxyfen 1.0WDG (0.01 to 0.05 ppm). Mortality increased from 16% to 87% with the increase in Pyriproxyfen concentration. Mortality with 0.05 and 0.01 ppm concentration after 21 days of treatment was 87 and 16%, respectively. It was 10% in control. Inhibition decreased from 48% to 13% with the increase in IGR concentration, where it was 48% with 0.01 ppm concentration and 13% with 0.05 ppm. Deformity in *Culex* spp. was highest of 27% with 0.04 ppm concentration of IGR and lowest of 2% in control. Adult emergence was highest (88%) in control and lowest (2%) with 0.01 ppm of the IGR. The overall mean mortality was 42.7%, inhibition was 29%, deformity was 11.3% and adult emergence was 15% with application of different concentrations of the IGR (0.01 to 0.05 ppm).

Various concentrations (0.01 to 0.05) of Methoprene had significantly different effect on growth inhibition and other biological parameters of *Aedes* spp. (Table 4.4.4). After 21 days of Methoprene treatment *Aedes* spp. mortality was highest (36%) with the higher concentration (0.05 ppm) and lowest (8%) in control. Inhibition increased from 31% to 58% with the increase in Methoprene concentration from 0.01 to 0.05 ppm. High deformity of mosquitoes (20%) was recorded with 0.02 ppm as compared to only 6% with 0.05 ppm. *Aedes* spp. adult emergence decreased from 49% to 0.00 with increase of Methoprene concentration (0.01 to 0.05 ppm). Different concentrations of Methoprene resulted in *Aedes* spp. overall mean mortality of 21.7%, inhibition of 38%, deformity of 10.8% and adult emergence of 30.2%.

Application of different concentrations (0.01 to 0.05 ppm) of Pyriproxyfen 0.5WDG yielded significantly different effect on mortality, deformities, emergence and inhibition of *Aedes* spp. (Table 4.4.5). With the increase in IGR concentration from 0.01 to 0.05 ppm mortality increased from 8% to 73%, recorded 21 days after treatment. Maximum inhibition of 63% was recorded at 0.02 ppm concentration. With the increase in IGR concentration (from 0.02 to 0.05 ppm) *Aedes* spp. deformity reduced from 18% to 7%. No deformity was observed in control. Application of different concentrations (0.01 to 0.05 ppm) of the IGR resulted in overall mean of 33% mortality, 37% inhibition, 11% deformity and 20% adult emergence of *Aedes* spp.
The application of Pyriproxyfen 1.0WDG at different concentrations (0.01 to 0.05 ppm) against *Aedes* spp. showed significant variations in mortalities, deformities, adult emergence (Table 4.4.6). *Aedes* spp. mortality increased from 7 to 78% with the increase in Pyriproxyfen concentration from 0.01 to 0.05%, recorded 21 days after treatment. *Aedes* spp. inhibition decreased from 45% to 15% with the increase in IGR concentration from 0.01 to 0.05 ppm. *Aedes* spp. deformity of was higher of 26% with 0.02 ppm and lower of 7% with 0.05 ppm. No deformity was observed in control. Adult emergence was highest (91%) in control and lowest (22%) with 0.05 ppm of the IGR. Application of different concentrations (0.01 to 0.05 ppm) of the IGR against *Aedes* spp. yielded overall mean of 34% mortality, 29% inhibition, 14% deformity and 22% adult emergence.

**Field application of IGR against mosquito *Aedes* and *Culex* species**

The efficacy of IGR, Pyriproxyfen 1.0WDG after field application were tested by sampling from 1 to 6 months and tested against laboratory reared *Culex* spp., resulted in significant variations in mortalities, inhibition, deformities and adult emergence (Table 4.4.7). Highest mortality (50%) of *Culex* larvae was recorded after 01 month and lowest mortality (10%) after 6 months period. Highest inhibition of 47% in *Culex* spp. was noted after 3 to 4 months duration and lowest of 20% after 6 months period. Minimum deformed larvae (7%) were noted after 01 month and higher (21%) after 3 months experimental period. No inhibition or malformations of larvae were found in control. However, the larvicidal effect of IGR against field collected *Culex* spp., collected after 01 to 6 months duration, were similar. In control *Culex* spp. adult emergence was highest (88%) at initial stage of collection and lowest (14%) after 4 months of collection. It further increased from 33 to 58% in 5-6 months collected individuals. Applications of IGR, during 1 to 6 months duration, against field collected *Culex* spp. yielded overall mean of mortality of 26%, inhibition of 33%, deformity of 13% and adult emergence of 27%.

The efficacy of IGR, Pyriproxyfen 1.0WDG after field application were tested by sampling from 1 to 6 months and tested against laboratory reared *Aedes* spp., resulted in significant variations in mortalities, inhibition, deformities and adult emergence (Table 4.4.8). *Aedes* spp. mortality decreased during the test period, where it was highest of 46% after 1 month and lowest of 8% after 6 months. Larval inhibition
was highest (58%) after 4 months and lowest (35%) after 6 months period. Minimum deformed larvae (15%) were recorded after 01 and 4 months period, and maximum (19%) after 2 months duration. No inhibition or malformation of larvae was noted in control. Efficacy of IGRs against field collected, after 01 to 6 months duration, *Aedes* spp. larvae were similar. Minimum (5%) *Aedes* spp. larval deformities were recorded after 4 months of exposure to the IGR. Experimental results of IGR testing against field collected *Aedes* spp. after 1 to 6 months duration gave overall mean of 23% mortality, 39% inhibition, 14% deformity and 23% adult emergence.

Table 4.4.9 indicates LC$_{50}$, LC$_{90}$, lower and upper confidence limits, slope and chi square ($\chi^2$) values of the three insect growth regulators (IGRs) for 21 days exposure of *Aedes albopictus* and *Culex quinquefasciatus*. The results showed highest LC$_{50}$ value (0.014 ppm) and LC$_{90}$ value (0.092 ppm) for Methoprene and the least (0.002 ppm) and (0.010 ppm) for Pyriproxyfen against *Culex spp*. Similarly in case of *Aedes spp.*, maximum LC$_{50}$ (0.016 ppm) and LC$_{90}$ value (0.115 ppm) were recorded for Methoprene and minimum (0.002 ppm) and (0.008 ppm) for Pyriproxyfen. Overall, LC$_{50}$ & LC$_{90}$ values were maximum for Methoprene indicating its low toxicity while Pyriproxyfen (1.0 WDG) gave minimum LC$_{50}$ & LC$_{90}$ values that exhibited high toxicity against the two mosquito species.

Table (4.4.10) shows the adult emergence inhibition induced by the three insect growth regulators (IGRs) against *Aedes* and *Culex* spp. The results demonstrated significant variations among the tested chemicals. Highest adult emergence inhibition (99.05%) was observed in Pyriproxyfen (1.0 WDG) and the least in Methoprene (83.680 %) against *Culex* spp. Similarly in case of *Aedes spp.*, minimum adult emergence inhibition was recorded in Methoprene (79.043%) and maximum (93.297 %) in Pyriproxyfen (1.0 WDG).
Table 4.4.1  Efficacy of methoprene on *Culex* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Conc.(ppm)</th>
<th>Biological parameters (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortality</td>
</tr>
<tr>
<td>0.00 (control)</td>
<td>7(^{k\text{lm}})</td>
</tr>
<tr>
<td>0.01</td>
<td>10(^{k})</td>
</tr>
<tr>
<td>0.02</td>
<td>19(^{ij})</td>
</tr>
<tr>
<td>0.03</td>
<td>20(^{ij})</td>
</tr>
<tr>
<td>0.04</td>
<td>28(^{f\text{gh}})</td>
</tr>
<tr>
<td>0.05</td>
<td>40(^{b})</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>20.7(^{b})</td>
</tr>
</tbody>
</table>

Standard deviation  = 19.27  
Standard error  = 1.97  
LSD value at 0.05% for biological parameters = 3.07  
LSD value at 0.05% for interaction = 7.53.  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
## Table 4.4.2  Efficacy of pyriproxyfen 0.5 WDG on *Culex* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Conc.(ppm)</th>
<th>Biological parameters (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortality</td>
<td>Inhibition</td>
<td>Deformity</td>
<td>Emergence</td>
</tr>
<tr>
<td>0.00 (control)</td>
<td>10&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>0&lt;sup&gt;j&lt;/sup&gt;</td>
<td>2&lt;sup&gt;l&lt;/sup&gt;</td>
<td>88&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.01</td>
<td>10&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>54&lt;sup&gt;c&lt;/sup&gt;</td>
<td>22&lt;sup&gt;f&lt;/sup&gt;</td>
<td>10&lt;sup&gt;hi&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.02</td>
<td>23&lt;sup&gt;f&lt;/sup&gt;</td>
<td>47&lt;sup&gt;d&lt;/sup&gt;</td>
<td>17&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>5&lt;sup&gt;ij&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.03</td>
<td>30&lt;sup&gt;e&lt;/sup&gt;</td>
<td>48&lt;sup&gt;sd&lt;/sup&gt;</td>
<td>17&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>5&lt;sup&gt;ij&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.04</td>
<td>47&lt;sup&gt;d&lt;/sup&gt;</td>
<td>43&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>0&lt;sup&gt;j&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.05</td>
<td>67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22&lt;sup&gt;f&lt;/sup&gt;</td>
<td>11&lt;sup&gt;ghi&lt;/sup&gt;</td>
<td>0&lt;sup&gt;j&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>31.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.7&lt;sup&gt;d&lt;/sup&gt;</td>
<td>18&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 23.54  
Standard error = 2.40  
LSD value at 0.05% for biological parameters = 2.65  
LSD value at 0.05% for interaction = 6.49.  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.4.3. Efficacy of pyriproxyfen 1.0WDG on *Culex* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Conc. (ppm)</th>
<th>Biological parameters (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortality</td>
<td>Inhibition</td>
<td>Deformity</td>
<td>Emergence</td>
</tr>
<tr>
<td>0.00 (control)</td>
<td>10&lt;sup&gt;i&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
<td>2&lt;sup&gt;i&lt;/sup&gt;</td>
<td>88&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.01</td>
<td>16&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>48&lt;sup&gt;c&lt;/sup&gt;</td>
<td>27&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.02</td>
<td>37&lt;sup&gt;e&lt;/sup&gt;</td>
<td>43&lt;sup&gt;d&lt;/sup&gt;</td>
<td>16&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.03</td>
<td>45&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>35&lt;sup&gt;e&lt;/sup&gt;</td>
<td>19&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.04</td>
<td>61&lt;sup&gt;h&lt;/sup&gt;</td>
<td>35&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4&lt;sup&gt;l&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>0.05</td>
<td>87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>42.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>15.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 26.55  
Standard error = 2.71  
LSD value at 0.05% for biological parameters = 2.03  
LSD value at 0.05% for interaction = 4.96  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.4.4. Efficacy of methoprene on *Aedes* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Conc.(ppm)</th>
<th>Biological parameters (%)</th>
<th>Mortality</th>
<th>Inhibition</th>
<th>Deformity</th>
<th>Emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00 (control)</td>
<td></td>
<td>8&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
<td>90&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>0.01</td>
<td></td>
<td>11&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>31&lt;sup&gt;de&lt;/sup&gt;</td>
<td>12&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>49&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
<tr>
<td>0.03</td>
<td></td>
<td>27&lt;sup&gt;e&lt;/sup&gt;</td>
<td>49&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>9&lt;sup&gt;gh&lt;/sup&gt;</td>
</tr>
<tr>
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<td></td>
<td>33&lt;sup&gt;de&lt;/sup&gt;</td>
<td>53&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>12&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>2&lt;sup&gt;ij&lt;/sup&gt;</td>
</tr>
<tr>
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<td></td>
<td>36&lt;sup&gt;d&lt;/sup&gt;</td>
<td>58&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6&lt;sup&gt;hij&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>Overall Mean</td>
<td></td>
<td>217&lt;sup&gt;c&lt;/sup&gt;</td>
<td>38.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>30.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 22.58  
Standard error = 2.30  
LSD value at 0.05% for biological parameters = 2.54  
LSD value at 0.05% for interaction = 6.23  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.4.5. Efficacy of pyriproxyfen 0.5WDG on *Aedes* spp. larval mortality, inhibition, deformity and emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Conc.(ppm)</th>
<th>Effect on biological parameters (%)</th>
<th>Mortality</th>
<th>Inhibition</th>
<th>Deformity</th>
<th>Emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 (control)</td>
<td></td>
<td>7ij</td>
<td>0k</td>
<td>0k</td>
<td>94a</td>
</tr>
<tr>
<td>0.01</td>
<td></td>
<td>8l</td>
<td>55d</td>
<td>16h</td>
<td>21g</td>
</tr>
<tr>
<td>0.02</td>
<td></td>
<td>16h</td>
<td>63c</td>
<td>18gh</td>
<td>3jk</td>
</tr>
<tr>
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<td></td>
<td>40ef</td>
<td>44e</td>
<td>16h</td>
<td>0k</td>
</tr>
<tr>
<td>0.04</td>
<td></td>
<td>52d</td>
<td>39f</td>
<td>9i</td>
<td>0k</td>
</tr>
<tr>
<td>0.05</td>
<td></td>
<td>73b</td>
<td>20h</td>
<td>7ij</td>
<td>0k</td>
</tr>
<tr>
<td>Overall Mean</td>
<td></td>
<td>32.7b</td>
<td>36.8a</td>
<td>11.0d</td>
<td>19.7c</td>
</tr>
</tbody>
</table>

Standard deviation = 26.13     Standard error  = 2.67
LSD value at 0.05% for biological parameters = 1.74
LSD value at 0.05% for interaction = 4.25
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.4.6. Efficacy of pyriproxyfen 1.0WDG on *Aedes* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Conc. (ppm)</th>
<th>Mortality</th>
<th>Inhibition</th>
<th>Deformity</th>
<th>Emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 (control)</td>
<td>7&lt;sup&gt;i&lt;/sup&gt;</td>
<td>0&lt;sup&gt;k&lt;/sup&gt;</td>
<td>0&lt;sup&gt;k&lt;/sup&gt;</td>
<td>91&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.01</td>
<td>7&lt;sup&gt;i&lt;/sup&gt;</td>
<td>45&lt;sup&gt;d&lt;/sup&gt;</td>
<td>24&lt;sup&gt;f,g&lt;/sup&gt;</td>
<td>22&lt;sup&gt;f,h&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.02</td>
<td>19&lt;sup&gt;ghi&lt;/sup&gt;</td>
<td>37&lt;sup&gt;e&lt;/sup&gt;</td>
<td>26&lt;sup&gt;f&lt;/sup&gt;</td>
<td>18&lt;sup&gt;hi&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.03</td>
<td>37&lt;sup&gt;e&lt;/sup&gt;</td>
<td>43&lt;sup&gt;d&lt;/sup&gt;</td>
<td>20&lt;sup&gt;ghi&lt;/sup&gt;</td>
<td>0&lt;sup&gt;k&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.04</td>
<td>55&lt;sup&gt;c&lt;/sup&gt;</td>
<td>37&lt;sup&gt;e&lt;/sup&gt;</td>
<td>8&lt;sup&gt;i&lt;/sup&gt;</td>
<td>0&lt;sup&gt;k&lt;/sup&gt;</td>
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<tr>
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<td>7&lt;sup&gt;i&lt;/sup&gt;</td>
<td>0&lt;sup&gt;k&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14&lt;sup&gt;d&lt;/sup&gt;</td>
<td>22&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 24.39  
Standard error = 2.49  
LSD value at 0.05% for biological parameters = 2.29  
LSD value at 0.05% for interaction = 5.60  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.4.7. Efficacy of IGRs 1.0 WDG after field application on *Culex* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Duration (months)</th>
<th>Effect on biological parameters (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortality</td>
<td>Inhibition</td>
<td>Deformity</td>
<td>Emergence</td>
</tr>
<tr>
<td>0 (control)</td>
<td>10&lt;sup&gt;ijk&lt;/sup&gt;</td>
<td>0&lt;sup&gt;l&lt;/sup&gt;</td>
<td>0&lt;sup&gt;l&lt;/sup&gt;</td>
<td>88&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>1</td>
<td>50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>43&lt;sup&gt;de&lt;/sup&gt;</td>
<td>7&lt;sup&gt;k&lt;/sup&gt;</td>
<td>0&lt;sup&gt;l&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>41&lt;sup&gt;e&lt;/sup&gt;</td>
<td>42&lt;sup&gt;de&lt;/sup&gt;</td>
<td>17&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
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<tr>
<td>3</td>
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<td>47&lt;sup&gt;cde&lt;/sup&gt;</td>
<td>21&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>0&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>24&lt;sup&gt;g&lt;/sup&gt;</td>
<td>47&lt;sup&gt;cd&lt;/sup&gt;-&lt;sup&gt;e&lt;/sup&gt;</td>
<td>17&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>14&lt;sup&gt;ij&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>17&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>34&lt;sup&gt;f&lt;/sup&gt;</td>
<td>16&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>33&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>10&lt;sup&gt;ijk&lt;/sup&gt;</td>
<td>20&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>12&lt;sup&gt;ijk&lt;/sup&gt;</td>
<td>58&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Overall Mean</td>
<td>26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13&lt;sup&gt;c&lt;/sup&gt;</td>
<td>27&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 21.20  
Standard error = 2.00  
LSD value at 0.05% for biological parameters = 1.98  
LSD value at 0.05% for interaction = 5.23  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.4.8. Efficacy of IGRs 1.0 WDG after field application on *Aedes* spp. larval mortality, inhibition, deformity and adult emergence during 2011-2012.

<table>
<thead>
<tr>
<th>Duration (months)</th>
<th>Biological parameters (%)</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mortality</td>
<td>Inhibition</td>
<td>Deformity</td>
<td>Emergence</td>
</tr>
<tr>
<td>0 (control)</td>
<td>7&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>0&lt;sup&gt;o&lt;/sup&gt;</td>
<td>0&lt;sup&gt;o&lt;/sup&gt;</td>
<td>93&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>46&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>40&lt;sup&gt;efg&lt;/sup&gt;</td>
<td>15&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>0&lt;sup&gt;o&lt;/sup&gt;</td>
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<td>0&lt;sup&gt;o&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>32&lt;sup&gt;h&lt;/sup&gt;</td>
<td>50&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
<td>4</td>
<td>22&lt;sup&gt;ij&lt;/sup&gt;</td>
<td>58&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>5&lt;sup&gt;no&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>12&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>48&lt;sup&gt;c&lt;/sup&gt;</td>
<td>16&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>24&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>8&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>35&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>16&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>41&lt;sup&gt;def&lt;/sup&gt;</td>
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<td>Mean</td>
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<td>39.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>23.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 22.07  Standard error = 2.08
LSD value at 0.05% for biological parameters = 2.09
LSD value at 0.05% for interaction = 5.52
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).  

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Table 4.4.9. Comparative toxicity of insect growth regulators (IGRs) to laboratory-reared 3rd instar larvae of *Aedes albopictus* and *Culex quinquefasciatus* exposed continuously for 21 days to the IGRs in the laboratory bioassays.

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment (0.01-0.05ppm)</th>
<th>Lethal dose concentration (ppm)</th>
<th>Slope</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LC$<em>{50}$          95%CL     LC$</em>{90}$ 95%CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Culex</em></td>
<td>Methoprene</td>
<td>0.014              0.005-0.020 0.092</td>
<td>0.054-0.512</td>
<td>1.575± 0.264</td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 0.5 WDG</td>
<td>0.005              0.001-0.009 0.017</td>
<td>0.012-0.026</td>
<td>2.593±0.429</td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 1.0WDG</td>
<td>0.002              0.000-0.004 0.010</td>
<td>0.004-0.014</td>
<td>1.681±0.493</td>
</tr>
<tr>
<td><em>Aedes</em></td>
<td>Methoprene</td>
<td>0.016              0.011-0.020 0.115</td>
<td>0.076-0.255</td>
<td>1.502±0.263</td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 0.5 WDG</td>
<td>0.006              0.001-0.010 0.023</td>
<td>0.015-0.040</td>
<td>2.147±0.345</td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 1.0WDG</td>
<td>0.002              0.000-0.004 0.008</td>
<td>0.003-0.012</td>
<td>1.898±0.591</td>
</tr>
</tbody>
</table>
### Table 4.4.10. Comparative adult emergence inhibition defected by different IGRs against *Aedes* and *Culex* spp.

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment</th>
<th>Mean emergence inhibition (%)</th>
<th>Critical value at 0.05% for comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culex</td>
<td>Methoprene</td>
<td>83.680&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.4407</td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 0.5 WDG</td>
<td>95.050&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 1.0 WDG</td>
<td>99.500&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Aedes</td>
<td>Methoprene</td>
<td>79.043&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.9038</td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 0.5 WDG</td>
<td>91.400&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pyriproxyfen 1.0 WDG</td>
<td>93.297&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Means in columns for each specie group followed by the same letters are not significantly different at 0.05% level of probability using LSD test.
4.5 Larvicidal efficacy of plant extract (phyto-chemicals) against *Culex* and *Aedes* Spp.

Efficacy of larvicidal activities of Chrysanthemum, Parthenium, Neem extract, Neem oil and Stevia against *Culex* and *Aedes* spp. was compared with commercial larvicide. The efficacy of extracts was assessed in various concentrations against 3rd and 4th instar larvae of the respective mosquito species and data was recorded after 24 and 48 hours exposures periods. The results of the experiments are presented in tables 4.5.1 to 4.5.20.

4.5.1 Chrysanthemum extracts

Various concentrations of Chrysanthemum extracts gave significantly different effect against third instar larvae of *Culex* spp. With the increase in chrysanthemum concentration from 0.5 to 5%, mortality increased from 15.5% to 91.5% (Table 4.5.1). Mortality after 24 hour exposure was 48.5% and it increased to 55% after 48 hours. Mortality was lowest of 13% with 0.5% concentration of chrysanthemum after 24h but it increased to highest figure of 96% at increased concentration of 5% after 48 hour. In control lowest mortality of 3% was noted.

Various concentrations of chrysanthemum extracts had significant effect on fourth instar larvae of *Culex* spp. (Table 4.5.2). With the increase in chrysanthemum concentration from 0.5 to 5% mortality increased from 8% to 83%. Mortality also increased with exposure time, where it increased from 42.1% at 24h to 47.7% at 48h. Highest mortality (87%) was achieved with 5% concentration of chrysanthemum after 48 hour exposure. Temephos (standard check) yielded highest mortality of 94%. In control lowest mortality of 5% was observed.

Various concentrations of chrysanthemum resulted in significantly different mortalities in third instar larvae of *Aedes* spp. (Table 4.5.3). Highest mortality of 100% was achieved with 5% chrysanthemum concentration and 19.5% with 0.5% concentration. Mortality also increased with chrysanthemum exposure time, where it was 58.5% after 24 hour, and it increased to 64.1% after 48 hours. After 48 hour exposure, highest mortality (100%) was recorded each with chrysanthemum 5% extract and Temephos 50 EC. Lowest mortality of 7% was observed in control after 24 hour exposure.
Chrysanthemum extracts applied against fourth instar larvae of *Aedes spp.* showed significantly different results (Table 4.5.4). *Aedes* spp. larval mortalities increased from 16.5% to 95% with the increase in chrysanthemum concentration from 0.5 to 5%. Mortalities in *Aedes* spp. larvae increased from 55.1% to 62.2% with increase in exposure time from 24 to 48h. Highest mortality of 97% and 100% was recorded with 5% concentration of chrysanthemum and Temephos after 48h, respectively. Lowest mortality of 5% was noted in control after 24 hour exposure.

### 4.5.2 Neem extracts

*Culex* spp. treated with different concentrations of neem extracts gave considerable variable results (Table 4.5.5). Higher dose (5%) of neem extract gave higher mortality of 95.5% as compared to 10.5% mortality recorded with 0.5% dose. Mortality was lower of 52.4% after 24 hour exposure, which increased to 58.1% after 48 hours exposure period. *Culex spp.* mortality was highest of 98% with 5% extract and 100% with Temephos 50 EC after 48 hour exposure. It was lowest of 3% in control.

Neem extracts tested in different concentrations (0.5 to 5%) against fourth instar larvae of *Culex* spp. gave variable mortalities, where it ranged from 8.5% (0.5% concentration) to 88.5% (5% concentration) (Table 4.5.6). *Culex spp.* mortalities increased from 47.9% to 54.4% with increase in exposure period from 24 to 48h. After 48 hour, highest mortality of 93% and 99% was recorded with 5% neem extract and standard dose of Temephos 50 EC, respectively, whereas lowest mortality of 13% was noticed in control at this time period.

Neem extracts tested in various concentrations (0.5 to 5%) against third instar larvae of *Aedes* spp. gave significantly variable mortalities, where it ranged from 17% to 95.5% (Table 4.5.7). Highest mortality (95.5%) was noted with 5% Neem extract. Increase in exposure period from 24 to 48h resulted in increase in mortalities from 57.2% to 62.7%. Highest mortality of 96% and 100% was recorded with 5% neem extract and Temephos 50 EC after 48h exposure, respectively. In control only 10% mortality was noted in control after 24 hour exposure.
Neem extract tested in variable concentrations against fourth instar larvae of *Aedes spp.* affected variable and significantly different mortalities, where it ranged from 15% (0.5% conc.) to 94% (5% conc.) see Table 4.5.8. Maximum mortality of 94% was achieved with 5% neem extract. Increase in exposure time from 24 to 48h affected increase in mortalities from 54 to 61.4%. Highest mortality of 97% and 98% was recorded with 5% neem extract and Temephos at the recommended rate after 48 hour exposure, respectively. Lowest mortality of 11% was noted in natural control (tap water) after 24 hour exposure.

4.5.3 Parthenium extracts

Significantly variable mortalities were found in third instar larvae of *Culex spp.* treated with different doses of Parthenium extract (Table 4.5.9). The mortalities increased from 17.5% to 100% with increase in Parthenium extract concentration from 0.5 to 5%. Higher concentration of Parthenium extract (5%) gave 100% mortalities. Exposure period also affected mortalities, where it was 56.9% after 24 hour exposure and 63.7% after 48 hours. Highest mortality (100%) was recorded with 5% extract after 48 hour exposure. Temephos at recommended dose yielded higher mortalities of 90% and 94% after 24 and 48 hour, respectively. In control lowest mortalities of 3% were observed.

Fourth instar larvae of *Culex spp.* treated with different doses of Parthenium extracts gave significantly variable mortalities, where it was 9% with 0.5% conc. and 94.5% with 5% conc. (Table 4.5.10). After 24h exposure, 45.6% mortality was recorded, which increased after 48h to 54.2%. Highest mortality (97%) was recorded after 48h with 5% extract and with Temephos (96%) at the recommended dose. In natural control lowest mortalities (3%) were noted.

*Aedes* spp. third instar larvae treated with different doses of Parthenium extract resulted in significantly different mortalities of 28.5% (0.5% conc.) to 100% (5% conc.) (Table 4.5.11). Maximum mortality (100%) was noted with 5% Parthenium extract. Mortalities in *Aedes spp.* larvae increased from 63.4% after 24h exposure time to 69.6% after 48h exposure. Five percent extract of Parthenium after 24h and Temephos at the recommended rate after 48h yielded highest mortalities of 100% and 96%, respectively. Lowest mortality (3%) was noted in control after 24 h.
Parthenium extracts applied in different concentrations (0.5 to 5%) resulted in significantly different mortalities in fourth instar larvae of *Aedes* spp. (Table 4.5.12). Mortalities increased from 11% to 100% when the dose of Parthenium extract was increased from 0.5 to 5%. Maximum mortalities (100%) were recorded with 5% Parthenium extract. Mortalities were 54.7% and 64.5% after 24 and 48 hours, respectively. Temephos caused 97% mortality after 48 hour. In control mortalities were lowest of 3% after 24 hour exposure.

### 4.5.4 Stevia extracts

Stevia extract (0.5 to 5% concentrations) treatment of *Culex* spp. third instar larvae caused significantly different mortalities, which ranged from 6.5% to 55.5% (Table 4.5.13). Larval mortality was low of 34.9% after 24 hour exposure, which increased to 39.4% after 48 hours. Stevia extract at 5% concentration yielded highest mortality (58%) after 48 hour exposure. Temephos 50 EC at recommended dose caused 90 and 94% mortalities after 24 and 48 hours, respectively. Lowest mortality (7%) was noted in control after 24 hour exposure.

Stevia extract applied in 0.5 to 5% concentrations against fourth instar larvae of *Culex* spp. resulted in 6% to 53% mortalities, respectively (Table 4.5.14). Mortalities increased from 33.2% to 38.4% with the increase in exposure time from 24 to 48h. Highest mortalities of 55% were recorded with 5% extract after 48 hour and with Temephos (95%) after 24h. Lowest mortalities of 3% were noted in control

Third instar larvae of *Aedes* spp. treated with different concentrations of Stevia extracts yielded significantly different mortalities, where it ranged from 9% (0.5% conc.) to 55% (5% conc.) (Table4.5.15). *Aedes* spp. mortalities increased from 37.0 to 42.5% when exposure time was increased from 24 to 48h. After 48h exposure time, higher mortalities of 58% and 100% were achieved with 5% Stevia extract and Temephos 50 EC, respectively. Lowest mortality (3%) was noted in control after 24 hour exposure.
Stevia extract applied against fourth instar larvae of *Aedes* spp. gave significantly variable results (Table 4.5.16). Mortality ranged from 6% to 53.5% with the application of 0.5 to 5% Stevia extracts, respectively. Higher exposure time of 48h gave higher mortalities of 38.4% as compared to 33.2% affected by lower exposure time of 24h. Stevia extract at 5% and Temephos at the recommended rate yielded highest mortalities of 55% and 95% after 48h, respectively. Lowest mortalities of 4% were noted in control after 24 hour exposure.

### 4.5.5 Neem oil

Neem oil treatment of third instar larvae of *Culex* spp. yielded significantly different mortalities (Table 4.5.17). Mortalities were 13% with 0.2 ppm and 86% with 1.0 ppm. Mortalities increased from 43.1% to 52.7% with the increase in exposure time from 24 to 48h. After 48h exposure, Neem oil at 1.0 ppm and Temephos at the recommended rate each gave highest mortalities of 94%. After 24h, in control, however, lowest mortalities of 3% were observed.

When fourth instar larvae of *Culex* spp. were treated with different concentrations of Neem oil significantly variable mortalities were found, where the mortalities ranged from 11% to 78.5% with 0.2 ppm and 1.0 ppm, respectively (Table 4.5.18). Neem oil at 1.0 ppm caused higher mortality of 78.5% after 24h. With the increase in exposure time from 24 to 48h, mortalities increased from 41.6 to 49.0%. Neem oil at 1.0 ppm and Temephos at the recommended rate yielded highest mortalities of 83% and 94% after 48h, respectively. After 24h, in control, however, lowest mortalities of 3% were noticed.

Treatments of third instar larvae of *Aedes* spp. with 0.2 to 1.0 ppm neem oil yielded 21% to 88% mortalities, respectively (Table 4.5.19). Maximum mortality (88%) was noted after 24h with 1.0 ppm of Neem oil. With the increase in exposure time from 24 to 48h, mortalities increased from 49.8 to 59.0%. Highest mortalities of 97% and 100% were achieved after 24h with 1.0 ppm neem oil and Temephos at the recommended rate, respectively. Lowest mortality of 3% was noted in control after 24 hour exposure.
Variable mortalities were noted in fourth instar larvae of *Aedes spp.* treated with 0.2 to 1.0 ppm Neem oil (Table 4.5.20). The mortalities increased from 19.5% to 83.5% when the dose of Neem oil was increased from 0.2 to 1.0 ppm. Neem oil applied at 1.0 ppm gave higher mortality of 83.5% after 24. Mortalities increased from 46.6% to 53.7% when neem oil concentration was increased from 0.2 to 1.0 ppm. Neem oil at 1.0 ppm and Temephos at the recommended rate caused highest mortalities of 90 and 95% after 48h, respectively. In control after 24h, however, lowest mortalities of only 3% were noticed.
### Table 4.5.1. Efficacy of chrysanthemum extract against *Culex* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>90&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3&lt;sup&gt;k&lt;/sup&gt;</td>
<td>6&lt;sup&gt;k&lt;/sup&gt;</td>
<td>4.5&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
<td>13&lt;sup&gt;j&lt;/sup&gt;</td>
<td>18&lt;sup&gt;ij&lt;/sup&gt;</td>
<td>15.5&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>20&lt;sup&gt;i&lt;/sup&gt;</td>
<td>28&lt;sup&gt;h&lt;/sup&gt;</td>
<td>24.0&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>48&lt;sup&gt;g&lt;/sup&gt;</td>
<td>53&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>50.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>56&lt;sup&gt;f&lt;/sup&gt;</td>
<td>63&lt;sup&gt;e&lt;/sup&gt;</td>
<td>59.5&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>71&lt;sup&gt;d&lt;/sup&gt;</td>
<td>80&lt;sup&gt;c&lt;/sup&gt;</td>
<td>75.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>91.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>48.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>55.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Standard deviation = 32.73  
Standard error = 4.09

LSD value at 0.05% for dose = 4.48
LSD value at 0.05% for mortality period = 2.24
LSD value at 0.05% for interaction = 6.33

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.2. Efficacy of chrysanthemum extract against *Culex* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>91.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>5&lt;sup&gt;j&lt;/sup&gt;</td>
<td>9&lt;sup&gt;ji&lt;/sup&gt;</td>
<td>7.0&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
<td>5&lt;sup&gt;j&lt;/sup&gt;</td>
<td>11&lt;sup&gt;ji&lt;/sup&gt;</td>
<td>8.0&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>16&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.5&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>36&lt;sup&gt;g&lt;/sup&gt;</td>
<td>42&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>39.0&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>48&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>54&lt;sup&gt;de&lt;/sup&gt;</td>
<td>51.0&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
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<td>64&lt;sup&gt;c&lt;/sup&gt;</td>
<td>61.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>83.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>42.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 31.23  Standard error = 3.90  
LSD value at 0.05% for dose = 4.98  
LSD value at 0.05% for mortality period = 2.49  
LSD value at 0.05% for interaction = 7.05  
Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.3. Efficacy of chrysanthemum extract against *Aedes* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>7&lt;sup&gt;j&lt;/sup&gt;</td>
<td>12&lt;sup&gt;j&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
<td>17&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>22&lt;sup&gt;gh&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>29&lt;sup&gt;g&lt;/sup&gt;</td>
<td>37&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
<td>Mean</td>
<td>58.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>64.1&lt;sup&gt;a&lt;/sup&gt;</td>
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</tbody>
</table>

Standard deviation  = 34.73  
Standard error  = 4.34

LSD value at 0.05% for doses  = 5.03
LSD value at 0.05% for mortality period  = 2.52
LSD value at 0.05% for interaction  = 7.12

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.4. Efficacy of chrysanthemum extract against *Aedes* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>5&lt;sup&gt;m&lt;/sup&gt;</td>
<td>12&lt;sup&gt;l&lt;/sup&gt;</td>
<td>8.5&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
<td>14&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>19&lt;sup&gt;k&lt;/sup&gt;</td>
<td>16.5&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
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<td>34&lt;sup&gt;l&lt;/sup&gt;</td>
<td>30.0&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
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<td>61&lt;sup&gt;g&lt;/sup&gt;</td>
<td>57.0&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>68&lt;sup&gt;f&lt;/sup&gt;</td>
<td>79&lt;sup&gt;e&lt;/sup&gt;</td>
<td>73.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>82&lt;sup&gt;de&lt;/sup&gt;</td>
<td>88&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>85.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
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<td>97&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>95.0&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>61.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 34.30  \[\text{Standard error} = 4.29\]

LSD value at 0.05% for doses = 4.39

LSD value at 0.05% for mortality period = 2.19

LSD value at 0.05% for interaction = 6.21

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.5. Efficacy of neem extract against *Culex* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
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<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>98\textsuperscript{ab}</td>
<td>100\textsuperscript{a}</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3\textsuperscript{j}</td>
<td>6\textsuperscript{kl}</td>
</tr>
<tr>
<td>0.5</td>
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<td>12\textsuperscript{j}</td>
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<tr>
<td>1</td>
<td>19\textsuperscript{i}</td>
<td>29\textsuperscript{h}</td>
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<tr>
<td>2</td>
<td>54\textsuperscript{g}</td>
<td>61\textsuperscript{f}</td>
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<tr>
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<td>67\textsuperscript{c}</td>
<td>72\textsuperscript{de}</td>
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<tr>
<td>4</td>
<td>76\textsuperscript{d}</td>
<td>87\textsuperscript{c}</td>
</tr>
<tr>
<td>5</td>
<td>93\textsuperscript{b}</td>
<td>98\textsuperscript{ab}</td>
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<tr>
<td>Mean</td>
<td>52.4\textsuperscript{b}</td>
<td>58.1\textsuperscript{a}</td>
</tr>
</tbody>
</table>

Standard deviation = 35.92  
Standard error = 4.49  
LSD value at 0.05% for doses = 3.94  
LSD value at 0.05% for mortality period = 1.97  
LSD value at 0.05% for interaction = 5.57  
Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.6. Efficacy of neem extract against *Culex* spp. 4\(^{th}\) instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
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<th>Mean Mortality (%)</th>
</tr>
</thead>
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<tr>
<td>Standard</td>
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<td>99(^a)</td>
</tr>
<tr>
<td>0 (control)</td>
<td>9(^i)</td>
<td>13(^j)</td>
</tr>
<tr>
<td>0.5</td>
<td>7(^j)</td>
<td>10(^i)</td>
</tr>
<tr>
<td>1</td>
<td>17(^{ij})</td>
<td>25(^{j})</td>
</tr>
<tr>
<td>2</td>
<td>41(^h)</td>
<td>52(^{g})</td>
</tr>
<tr>
<td>3</td>
<td>58(^{fg})</td>
<td>64(^{ef})</td>
</tr>
<tr>
<td>4</td>
<td>71(^{de})</td>
<td>79(^{sd})</td>
</tr>
<tr>
<td>5</td>
<td>84(^{bc})</td>
<td>93(^{ab})</td>
</tr>
<tr>
<td>Mean</td>
<td>47.9(^{b})</td>
<td>54.4(^a)</td>
</tr>
</tbody>
</table>

Standard deviation = 33.77  
Standard error = 4.22

LSD value at 0.05% for doses = 7.24
LSD value at 0.05% for mortality period = 3.62
LSD value at 0.05% for interaction = 10.24

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.7. Efficacy of neem extract against *Aedes* spp. 3\textsuperscript{rd} instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
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<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>99\textsuperscript{ab}</td>
<td>100\textsuperscript{a}</td>
</tr>
<tr>
<td>0 (control)</td>
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<td>14\textsuperscript{hi}</td>
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<td>19\textsuperscript{ah}</td>
</tr>
<tr>
<td>1</td>
<td>23\textsuperscript{g}</td>
<td>34\textsuperscript{f}</td>
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<td>2</td>
<td>58\textsuperscript{e}</td>
<td>67\textsuperscript{d}</td>
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<tr>
<td>3</td>
<td>73\textsuperscript{d}</td>
<td>81\textsuperscript{c}</td>
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<tr>
<td>4</td>
<td>84\textsuperscript{c}</td>
<td>92\textsuperscript{b}</td>
</tr>
<tr>
<td>5</td>
<td>95\textsuperscript{ab}</td>
<td>96\textsuperscript{ab}</td>
</tr>
<tr>
<td>Mean</td>
<td>57.1\textsuperscript{b}</td>
<td>62.8\textsuperscript{a}</td>
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</tbody>
</table>

Standard deviation = 34.37  Standard error = 4.30
LSD value at 0.05% for doses = 5.32
LSD value at 0.05% for mortality period = 2.66
LSD value at 0.05% for interaction = 7.52
Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.8. Efficacy of neem extract against *Aedes* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>96&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>98&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>11&lt;sup&gt;h&lt;/sup&gt;</td>
<td>19&lt;sup&gt;h&lt;/sup&gt;</td>
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<tr>
<td>0.5</td>
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<td>17&lt;sup&gt;h&lt;/sup&gt;</td>
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<td>51&lt;sup&gt;f&lt;/sup&gt;</td>
<td>62&lt;sup&gt;e&lt;/sup&gt;</td>
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<tr>
<td>3</td>
<td>69&lt;sup&gt;de&lt;/sup&gt;</td>
<td>78&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>87&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>91&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>97&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>54.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>61.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 33.49  Standard error = 4.19  
LSD value at 0.05% for doses = 6.85  
LSD value at 0.05% for mortality period = 3.42  
LSD value at 0.05% for interaction = 9.69  

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).  

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Table 4.5.9. Efficacy of parthenium extract against *Culex* spp. 3\textsuperscript{rd} instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
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<tbody>
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<tr>
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<td>94\textsuperscript{ab}</td>
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<td>6\textsuperscript{f}</td>
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<td>12\textsuperscript{f}</td>
<td>23\textsuperscript{e}</td>
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<tr>
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<td>38\textsuperscript{d}</td>
</tr>
<tr>
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<td>59\textsuperscript{c}</td>
<td>65\textsuperscript{c}</td>
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<td>3</td>
<td>65\textsuperscript{c}</td>
<td>90\textsuperscript{b}</td>
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<td>4</td>
<td>92\textsuperscript{b}</td>
<td>94\textsuperscript{ab}</td>
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<tr>
<td>5</td>
<td>100\textsuperscript{a}</td>
<td>100\textsuperscript{a}</td>
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<tr>
<td>Mean</td>
<td>56.9\textsuperscript{b}</td>
<td>63.7\textsuperscript{a}</td>
</tr>
</tbody>
</table>

Standard deviation = 35.28  Standard error = 4.41
LSD value at 0.05% for doses = 4.29
LSD value at 0.05% for mortality period = 2.15
LSD value at 0.05% for interaction = 6.07

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.10. Efficacy of parthenium extract against *Culex* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
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<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
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<td>96&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>95.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
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<td>5&lt;sup&gt;i&lt;/sup&gt;</td>
<td>4.0&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
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<td>6&lt;sup&gt;i&lt;/sup&gt;</td>
<td>12&lt;sup&gt;i&lt;/sup&gt;</td>
<td>9.0&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
<td>1</td>
<td>18&lt;sup&gt;h&lt;/sup&gt;</td>
<td>27&lt;sup&gt;g&lt;/sup&gt;</td>
<td>22.5&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>30&lt;sup&gt;g&lt;/sup&gt;</td>
<td>47&lt;sup&gt;f&lt;/sup&gt;</td>
<td>38.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>48&lt;sup&gt;f&lt;/sup&gt;</td>
<td>66&lt;sup&gt;e&lt;/sup&gt;</td>
<td>57.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>73&lt;sup&gt;d&lt;/sup&gt;</td>
<td>84&lt;sup&gt;c&lt;/sup&gt;</td>
<td>78.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>45.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>54.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Standard deviation  = 35.43  Standard error  = 4.43
LSD value at 0.05% for doses  = 3.35
LSD value at 0.05% for mortality period  = 1.67
LSD value at 0.05% for interaction  = 4.73

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.11. Efficacy of parthenium extract on *Aedes* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>95&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>96&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>95.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
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<td>5&lt;sup&gt;i&lt;/sup&gt;</td>
<td>4.0&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
<td>24&lt;sup&gt;h&lt;/sup&gt;</td>
<td>33&lt;sup&gt;g&lt;/sup&gt;</td>
<td>28.5&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>47&lt;sup&gt;f&lt;/sup&gt;</td>
<td>54&lt;sup&gt;e&lt;/sup&gt;</td>
<td>50.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>68&lt;sup&gt;d&lt;/sup&gt;</td>
<td>77&lt;sup&gt;c&lt;/sup&gt;</td>
<td>72.5&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>74&lt;sup&gt;c&lt;/sup&gt;</td>
<td>92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>83.0&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98.0&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>5</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>69.6&lt;sup&gt;a&lt;/sup&gt;</td>
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</tr>
</tbody>
</table>

Standard deviation = 34.00  Standard error = 4.25
LSD value at 0.05% for doses = 4.04
LSD value at 0.05% for mortality period = 2.02
LSD value at 0.05% for interaction = 5.72

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.12. Efficacy of parthenium extract against *Aedes* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
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<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
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<td>97^a</td>
</tr>
<tr>
<td>0 (control)</td>
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<td>5^h</td>
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<td>0.5</td>
<td>11^g</td>
<td>24^f</td>
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<tr>
<td>1</td>
<td>29^f</td>
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<td>4</td>
<td>73^c</td>
<td>95^a</td>
</tr>
<tr>
<td>5</td>
<td>100^a</td>
<td>100^a</td>
</tr>
<tr>
<td>Mean</td>
<td>54.7^b</td>
<td>64.5^a</td>
</tr>
</tbody>
</table>

Standard deviation = 35.46  
Standard error = 4.43  
LSD value at 0.05% for doses = 3.65  
LSD value at 0.05% for mortality period = 1.82  
LSD value at 0.05% for interaction = 5.16  

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.13. Efficacy of stevia extract against *Culex* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
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<td>94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>7&lt;sup&gt;i&lt;/sup&gt;</td>
<td>9&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>8.0&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
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<td>8&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>6.5&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>18&lt;sup&gt;fg&lt;/sup&gt;</td>
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<tr>
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<td>37&lt;sup&gt;e&lt;/sup&gt;</td>
<td>30.0&lt;sup&gt;e&lt;/sup&gt;</td>
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<tr>
<td>3</td>
<td>39&lt;sup&gt;e&lt;/sup&gt;</td>
<td>42&lt;sup&gt;de&lt;/sup&gt;</td>
<td>40.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>47&lt;sup&gt;c&lt;/sup&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>49&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>48.0&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>5</td>
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<td>58&lt;sup&gt;b&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Mean</td>
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<td>39.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 27.51  Standard error = 3.44
LSD value at 0.05% for doses = 5.08
LSD value at 0.05% for mortality period = 2.54
LSD value at 0.05% for interaction = 7.18

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.14. Efficacy of stevia extract on *Culex* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24 hrs</th>
<th>Mortality (%) after 48 hrs</th>
<th>Mean Mortality (%)</th>
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</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>Standard</td>
<td>88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>91.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3&lt;sup&gt;j&lt;/sup&gt;</td>
<td>6&lt;sup&gt;j&lt;/sup&gt;</td>
<td>4.5&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5</td>
<td>5&lt;sup&gt;j&lt;/sup&gt;</td>
<td>7&lt;sup&gt;ij&lt;/sup&gt;</td>
<td>6.0&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>13&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>19&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>16.0&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>24&lt;sup&gt;g&lt;/sup&gt;</td>
<td>35&lt;sup&gt;f&lt;/sup&gt;</td>
<td>29.5&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>36&lt;sup&gt;f&lt;/sup&gt;</td>
<td>40&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>38.0&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>46&lt;sup&gt;de&lt;/sup&gt;</td>
<td>50&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>48.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>51&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>55&lt;sup&gt;e&lt;/sup&gt;</td>
<td>53.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>33.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 27.73  Standard error = 3.47
LSD value at 0.05% for doses = 4.85
LSD value at 0.05% for mortality period = 2.42
LSD value at 0.05% for interaction = 6.85

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.15. Efficacy of stevia extract against *Aedes* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>0.5</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>3</td>
<td>44</td>
<td>53</td>
</tr>
<tr>
<td>4</td>
<td>47</td>
<td>51</td>
</tr>
<tr>
<td>5</td>
<td>52</td>
<td>58</td>
</tr>
<tr>
<td>Mean</td>
<td>37.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 29.09  Standard error = 3.64
LSD value at 0.05% for doses = 5.01
LSD value at 0.05% for mortality period = 2.50

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.16. Efficacy of stevia extract against *Aedes* spp. 4\textsuperscript{th} instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>87</td>
<td>95</td>
</tr>
<tr>
<td>0 (control)</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>0.5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>40</td>
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<tr>
<td>4</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>Mean</td>
<td>33.2\textsuperscript{b}</td>
<td>38.4\textsuperscript{a}</td>
</tr>
</tbody>
</table>

Standard deviation = 27.62  Standard error = 3.45
LSD value at 0.05\% for doses = 5.13
LSD value at 0.05\% for mortality period = 2.57

Means in columns/rows followed by different letters are significantly different at 0.05\% level of probability (LSD test).
Table 4.5.17. Efficacy of neem oil against *Culex* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (ppm)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>90(^a)</td>
<td>94(^a)</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3(^e)</td>
<td>6(^e)</td>
</tr>
<tr>
<td>0.2</td>
<td>11(^fg)</td>
<td>15(^f)</td>
</tr>
<tr>
<td>0.4</td>
<td>30(^e)</td>
<td>34(^e)</td>
</tr>
<tr>
<td>0.6</td>
<td>38(^de)</td>
<td>46(^cd)</td>
</tr>
<tr>
<td>0.8</td>
<td>52(^c)</td>
<td>80(^b)</td>
</tr>
<tr>
<td>1</td>
<td>78(^b)</td>
<td>94(^a)</td>
</tr>
<tr>
<td>Mean</td>
<td>43.1(^b)</td>
<td>52.7(^a)</td>
</tr>
</tbody>
</table>

Standard deviation = 33.19  Standard error = 4.43
LSD value at 0.05% for doses = 5.75
LSD value at 0.05% for mortality period = 3.07
LSD value at 0.05% for interaction = 8.13

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.18. Efficacy of neem oil against *Culex* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (ppm)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>88&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>94&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3&lt;sup&gt;i&lt;/sup&gt;</td>
<td>6&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.2</td>
<td>9&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>13&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.4</td>
<td>26&lt;sup&gt;g&lt;/sup&gt;</td>
<td>32&lt;sup&gt;fg&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.6</td>
<td>37&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>42&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.8</td>
<td>54&lt;sup&gt;d&lt;/sup&gt;</td>
<td>73&lt;sup&gt;ce&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>74&lt;sup&gt;c&lt;/sup&gt;</td>
<td>83&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>41.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>49.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 31.69  Standard error = 4.23
LSD value at 0.05% for doses = 4.43
LSD value at 0.05% for mortality period = 2.37
LSD value at 0.05% for interaction = 6.26

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.19. Efficacy of neem oil against *Aedes* spp. 3\textsuperscript{rd} instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (ppm)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>100\textsuperscript{a}</td>
<td>100\textsuperscript{a}</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3\textsuperscript{h}</td>
<td>6\textsuperscript{h}</td>
</tr>
<tr>
<td>0.2</td>
<td>18\textsuperscript{g}</td>
<td>24\textsuperscript{g}</td>
</tr>
<tr>
<td>0.4</td>
<td>35\textsuperscript{f}</td>
<td>42\textsuperscript{e}</td>
</tr>
<tr>
<td>0.6</td>
<td>53\textsuperscript{d}</td>
<td>58\textsuperscript{cd}</td>
</tr>
<tr>
<td>0.8</td>
<td>60\textsuperscript{c}</td>
<td>86\textsuperscript{e}</td>
</tr>
<tr>
<td>1</td>
<td>80\textsuperscript{b}</td>
<td>97\textsuperscript{a}</td>
</tr>
<tr>
<td>Mean</td>
<td>49.8\textsuperscript{b}</td>
<td>59.0\textsuperscript{a}</td>
</tr>
</tbody>
</table>

Standard deviation = 33.72 \hspace{1cm} Standard error = 4.51

LSD value at 0.05% for doses = 4.40
LSD value at 0.05% for mortality period = 2.35
LSD value at 0.05% for interaction = 6.23

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
Table 4.5.20. Efficacy of neem oil against *Aedes* spp. 4\textsuperscript{th} instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (ppm)</th>
<th>Mortality (%) after</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>48 hrs</td>
</tr>
<tr>
<td>Standard</td>
<td>93(^a)</td>
<td>95(^a)</td>
</tr>
<tr>
<td>0 (control)</td>
<td>3(^j)</td>
<td>6(^j)</td>
</tr>
<tr>
<td>0.2</td>
<td>16(^i)</td>
<td>23(^h)</td>
</tr>
<tr>
<td>0.4</td>
<td>33(^g)</td>
<td>40(^f)</td>
</tr>
<tr>
<td>0.6</td>
<td>48(^d)</td>
<td>55(^d)</td>
</tr>
<tr>
<td>0.8</td>
<td>56(^d)</td>
<td>67(^c)</td>
</tr>
<tr>
<td>1</td>
<td>77(^b)</td>
<td>90(^a)</td>
</tr>
<tr>
<td>Mean</td>
<td>46.6(^b)</td>
<td>53.7(^a)</td>
</tr>
</tbody>
</table>

Standard deviation = 30.88  Standard error = 4.13
LSD value at 0.05% for doses = 3.63
LSD value at 0.05% for mortality period = 1.94
LSD value at 0.05% for interaction = 5.14

Means in columns/rows followed by different letters are significantly different at 0.05% level of probability (LSD test).
4.5.6 Comparative efficacy of phyto-chemicals against *Culex* and *Aedes* species of mosquitoes

The phyto-chemicals, i.e. Chrysanthemum, Parthenium, Neem oil, Neem extract, and Stevia, tested in the present experiments were compared for its efficacy against the mosquito species complex. The results are presented in tables 4.5.21 to 4.5.28.

The results of the various phyto-chemicals tested against 3rd instar larvae of *Culex* spp. revealed significantly different mortalities after 24h (Table 4.5.21). Among the five phyto-chemicals tested, parthenium extracts (0.5 to 5 %) resulted in higher mortalities (ranging from 12 to 100%), while Stevia extract in lowest mortalities (from 5 to 53%). In control, mortalities were lowest (3 to 7%). Over all mean mortalities were higher for Parthenium extract (52.14%) and lowest for Stevia extract (27.0%). Higher concentration (5 %) of the Phyto-chemicals yielded highest overall mean mortalities of 84.60% and lower concentrations gave lowest mortalities of 10.0%. In control mortalities were lowest and it ranged from 3 to 7%.

Among the five phyto-chemicals tested against 3rd instar larvae of *Culex* spp., parthenium extracts at all concentrations (0.5 to 5 %) resulted in higher mortalities (ranging from 23 to 100%), while Stevia extract in lowest mortalities (from 8 to 58%) after 48h (Table 4.5.22). Over all mean mortalities were higher for Parthenium extract (59.43%) and lowest for Stevia extract (31.57%). Higher concentration (5 %) of the Phyto-chemicals yielded highest overall mean mortalities of 89.20% and lower concentrations gave lowest mortalities of 15.20%. Lowest mortalities were observed in control where it ranged from 6 to 9%.

Among the five phyto-chemicals tested against 4th instar larvae of *Culex* spp., Parthenium, Neem extract and Chrysanthemum at 5.0 % yielded higher mortalities of 92.0%, 84% and 79% respectively after 24h exposure period (Table 4.5.23). Lowest mean mortalities were observed at all concentrations of Stevia extract (ranging from 5 to 51.0%). Neem extract gave higher overall mean mortality of 41.0% and Stevia extract yielded lower mortalities of 25.43%. Overall mean mortalities were lower (6.40%) with lower concentration of the all the phyto-chemicals and higher with higher concentrations (76.80%). In control mortalities were lowest and it ranged from 3 to 9%.
Among the five phyto-chemicals tested against 4th instar larvae of *Culex* spp., Parthenium extract, Neem extract and Neem oil at 5.0 % gave higher mortalities of 97.0%, 93% and 92% respectively after 48h exposure period (Table 4.5.24). Lowest mean mortalities were observed at all concentrations of Stevia extract (ranging from 7 to 55.0%). Neem oil gave higher overall mean mortality of 49.43% and Stevia extract yielded lower mortalities of 30.29%. Overall mean mortalities were lower (10.60%) with lower concentration of the all the phyto-chemicals and higher with higher concentrations (84.80%). In control mortalities were lowest, where it ranged from 5 to 13%.

Among the five phyto-chemicals tested against 3rd instar larvae of *Aedes* spp., higher mortalities were recorded by Parthenium extract at 5 % (100%) after 48h (Table 4.5.25). Chrysanthemum extract at 5 % also gave 100% mortalities. Lowest mean mortalities were observed with all concentrations of Stevia extract (ranging from 7 to 62.0%). Higher overall mean mortalities were recorded with Parthenium extract (58.86%) and lower with Stevia extract (31.43%). With the increase in botanical extract from 0.5 to 5 %, overall mean mortalities increased from 16.20 to 88.20%. Lowest mortalities (3 to 10%) were found in control.

Among the five phyto-chemicals tested against 3rd instar larvae of *Aedes* spp., higher mortalities were recorded with all concentrations of Parthenium extract after 48h, where it was 33% with 0.5 %, 54% with 1.0 %, 77% with 2.0 %, 92% with 3.0 %, and 100% with 4&5 % (Table 4.5.26). Hundred percent mortalities were also achieved with 5 % of Chrysanthemum extract. Stevia extract at all concentrations (from 0.5 to 5 %) gave lower mortalities in the range of 11 to 67%. Overall mean mortalities were higher with Parthenium extract (65.86%) and lower with Stevia extract (37.29%). With the increase in botanical extract concentration from 0.5 to 5 %, overall mean mortalities increased from 21.80 to 92.0%. In control mortalities were lowest from all the treatments and it ranged from 5 to 14%.

The results of efficacy of five phyto-chemicals tested against 4th instar larvae of *Aedes* spp., showed mortalities of 16% with 0.5 % and 33% with 1.0 % of Neem oil; 55% with 2.0 % and 71% with 3.0 % of Parthenium; 82% with 4.0 % of Chrysanthemum; and 100% with 5.0 % of Parthenium after 24h exposure period (Table 4.5.27). Stevia extract at all concentrations (from 0.5 to 5 %) gave lower mortalities in
the range of 7 to 53%. Overall mean mortalities were higher with Parthenium extract (48.86%) and lower with Stevia extract (27.14%). With the increase in botanical extract concentration from 0.5 to 5%, overall mean mortalities increased from 12.20 to 83.60%. In control mortalities were lowest from all the treatments and it ranged from 3 to 11%.

Efficacy of the five phyto-chemicals tested against 4th instar larvae of *Aedes* spp. revealed mortalities of 24% with 0.5% of Parthenium extract; 40% with 1.0% of Neem oil; and 70% with 2.0%, 87% with 3.0%, 95% with 4.0%, and 100% with 5.0% of Parthenium extract after 48h (Table 4.5.28). Mortalities were lower with all the concentrations (0.5 to 5%) of Stevia extract and it ranged from 8 to 57%. Highest overall mean mortalities of 59.86% were recorded with Parthenium extract (48.86%) and lowest with Stevia extract (31.71%). With the increase in botanical extract concentration from 0.5 to 5%, overall mean mortalities increased from 18.20 to 89.0%. In control mortalities were lowest from all the treatments and it ranged from 5 to 19%.

Table (4.5.29) indicates LC50, LC90, lower and upper confidence limits, slope and chi square ($\chi^2$) values of five different botanical extracts for 24 hr exposure of 3rd instar larvae of *Aedes albopictus* and *Culex quinquefasciatus*. The results showed highest LC50 value (2.815%) and LC90 value (8.533%) for Stevia extract and the least (1.024%) and (2.452%) for Parthenium extract against *Aedes* spp. Similarly in case of *Culex* spp, maximum LC50 (2.882%) and LC90 value (8.335%) were recorded for Stevia extract and minimum (1.446%) and (2.343%) for Parthenium extract. Overall, LC50 & LC90 values were found maximum for Stevia extract indicating its low toxicity while Parthenium extract gave minimum LC50 & LC90 values that exhibited high toxicity against the two mosquito species.

Table (4.5.30) indicates LC50, LC90, lower and upper confidence limits, slope and chi square ($\chi^2$) values of five different botanical extracts for 48 hr exposure of 3rd instar larvae of *Aedes albopictus* and *Culex quinquefasciatus*. The results showed highest LC50 value (2.086%) and LC90 value (5.836%) for Stevia extract and the least (0.849%) and (1.875%) for Parthenium extract against *Aedes* spp. Similarly in case of *Culex* spp, maximum LC50 (2.662 ppm) and LC90 value (8.480%) were recorded for Stevia extract and minimum (0.967%) and (2.085%) for Parthenium extract. Overall, LC50 & LC90 values were maximum for Stevia extract indicating its low toxicity while Parthenium
extract gave minimum LC50 & LC90 values that exhibited high toxicity against the two mosquito species.

Table (4.5.31) indicates LC50, LC90, lower and upper confidence limits, slope and chi square ($\chi^2$) values of five different botanical extracts for 24 hr exposure of 4th instar larvae of *Aedes albopictus* and *Culex quinquefasciatus*. The results showed highest LC50 value (2.544 %) and LC90 value (6.452 %) for Stevia extract and the least (1.455 ppm) and (2.638 ppm) for Parthenium extract against *Aedes* spp. Similarly in case of *Culex* spp., maximum LC50 (2.882 %) and LC90 value (8.335%) were recorded for Stevia extract and minimum (1.446%) and (2.343%) for Parthenium extract. Overall, LC50 & LC90 values were found maximum for Stevia extract indicating its low toxicity while Parthenium extract gave minimum LC50 & LC90 values that exhibited high toxicity against the two mosquito species.

Table (4.5.32) indicates LC50, LC90, lower and upper confidence limits, slope and chi square ($\chi^2$) values of five different botanical extracts for 48 hr exposure of 4th instar larvae of *Aedes albopictus* and *Culex quinquefasciatus*. The results showed highest LC50 value (2.254%) and LC90 value (6.527%) for Stevia extract and the least (1.287%) and (2.126%) for Parthenium extract against *Aedes* spp. Similarly in case of *Culex* spp., maximum LC50 (2.889%) and LC90 value (8.302%) were recorded for Stevia extract and minimum (1.543%) and (2.882%) for Parthenium extract. Overall, LC50 & LC90 values were found maximum for Stevia extract indicating its low toxicity while Parthenium extract gave minimum LC50 & LC90 values that exhibited high toxicity against the two mosquito species.
Table 4.5.21 Efficacy of botanical extracts against *Culex* spp. 3\(^{rd}\) instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Chrysanthemum</th>
<th>Parthenium</th>
<th>Neem extract</th>
<th>Neem oil</th>
<th>Stevia extract</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>13(^{lo})</td>
<td>12(^{mp})</td>
<td>9(^{nq})</td>
<td>11(^{nop})</td>
<td>5(^{pq})</td>
<td>10.00(^{f})</td>
</tr>
<tr>
<td>1</td>
<td>20(^{kl})</td>
<td>34(^{hi})</td>
<td>19(^{kln})</td>
<td>30(^{ij})</td>
<td>15(^{lnn})</td>
<td>23.60(^{e})</td>
</tr>
<tr>
<td>2</td>
<td>48(^{g})</td>
<td>59(^{ef})</td>
<td>54(^{fg})</td>
<td>38(^{h})</td>
<td>23(^{jk})</td>
<td>44.40(^{d})</td>
</tr>
<tr>
<td>3</td>
<td>56(^{f})</td>
<td>65(^{de})</td>
<td>67(^{d})</td>
<td>52(^{fg})</td>
<td>39(^{h})</td>
<td>55.80(^{c})</td>
</tr>
<tr>
<td>4</td>
<td>71(^{cd})</td>
<td>92(^{b})</td>
<td>76(^{c})</td>
<td>78(^{c})</td>
<td>47(^{g})</td>
<td>72.80(^{b})</td>
</tr>
<tr>
<td>5</td>
<td>87(^{b})</td>
<td>100(^{a})</td>
<td>93(^{ab})</td>
<td>90(^{b})</td>
<td>53(^{fg})</td>
<td>84.60(^{a})</td>
</tr>
<tr>
<td>Control</td>
<td>3(^{q})</td>
<td>3(^{q})</td>
<td>3(^{q})</td>
<td>3(^{q})</td>
<td>7(^{opq})</td>
<td>3.80(^{g})</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>42.57(^{c})</td>
<td>52.14(^{a})</td>
<td>45.86(^{b})</td>
<td>43.14(^{bc})</td>
<td>27.00(^{d})</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 31.13  
Standard error = 2.63

LSD value at 0.05\% for doses = 3.28
LSD value at 0.05\% for insecticides = 2.77
LSD value at 0.05\% for interaction = 7.34

Means in columns/rows followed by similar letters are not significantly different at 0.05\% level of probability (LSD test).
Table 4.5.22. Efficacy of botanical extracts against *Culex* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Chrysanthemum Mortality (%)</th>
<th>Parthenium Mortality (%)</th>
<th>Neem Mortality (%)</th>
<th>Neem Oil Mortality (%)</th>
<th>Stevia Mortality (%)</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>18&lt;sup&gt;pl&lt;/sup&gt;</td>
<td>23&lt;sup&gt;op&lt;/sup&gt;</td>
<td>12&lt;sup&gt;qs&lt;/sup&gt;</td>
<td>15&lt;sup&gt;qr&lt;/sup&gt;</td>
<td>8&lt;sup&gt;s&lt;/sup&gt;</td>
<td>15.20&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>28&lt;sup&gt;ho&lt;/sup&gt;</td>
<td>38&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>29&lt;sup&gt;no&lt;/sup&gt;</td>
<td>34&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>18&lt;sup&gt;pql&lt;/sup&gt;</td>
<td>29.40&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>53&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>65&lt;sup&gt;f&lt;/sup&gt;</td>
<td>61&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>46&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>37&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>52.40&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>63&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>90&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>72&lt;sup&gt;e&lt;/sup&gt;</td>
<td>80&lt;sup&gt;d&lt;/sup&gt;</td>
<td>42&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>69.40&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>4</td>
<td>80&lt;sup&gt;d&lt;/sup&gt;</td>
<td>94&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>94&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>49&lt;sup&gt;ji&lt;/sup&gt;</td>
<td>80.80&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>5</td>
<td>96&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>58&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>89.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>6&lt;sup&gt;s&lt;/sup&gt;</td>
<td>6&lt;sup&gt;s&lt;/sup&gt;</td>
<td>6&lt;sup&gt;s&lt;/sup&gt;</td>
<td>6&lt;sup&gt;s&lt;/sup&gt;</td>
<td>9&lt;sup&gt;rs&lt;/sup&gt;</td>
<td>6.60&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>49.14&lt;sup&gt;c&lt;/sup&gt;</td>
<td>59.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>52.71&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31.57&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Standard deviation = 32.75  
Standard error = 2.77

LSD value at 0.05% for doses = 2.84 
LSD value at 0.05% for insecticides = 2.40 
LSD value at 0.05% for interaction = 6.34 

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.5.23. Efficacy of botanical extracts against *Culex* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Chrysanthemum</th>
<th>Parthenium</th>
<th>Neem extract</th>
<th>Neem oil</th>
<th>Stevia extract</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>5&lt;sup&gt;q&lt;/sup&gt;</td>
<td>6&lt;sup&gt;pq&lt;/sup&gt;</td>
<td>7&lt;sup&gt;pq&lt;/sup&gt;</td>
<td>9&lt;sup&gt;opq&lt;/sup&gt;</td>
<td>5&lt;sup&gt;q&lt;/sup&gt;</td>
<td>6.40&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>16&lt;sup&gt;no&lt;/sup&gt;</td>
<td>18&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>17&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>26&lt;sup&gt;l&lt;/sup&gt;</td>
<td>13&lt;sup&gt;nop&lt;/sup&gt;</td>
<td>18.00&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>36&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>30&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>41&lt;sup&gt;ji&lt;/sup&gt;</td>
<td>37&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>24&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>33.60&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>48&lt;sup&gt;ghi&lt;/sup&gt;</td>
<td>48&lt;sup&gt;ghi&lt;/sup&gt;</td>
<td>58&lt;sup&gt;e&lt;/sup&gt;</td>
<td>54&lt;sup&gt;efg&lt;/sup&gt;</td>
<td>36&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>48.80&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>59&lt;sup&gt;e&lt;/sup&gt;</td>
<td>73&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>71&lt;sup&gt;d&lt;/sup&gt;</td>
<td>74&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>46&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>64.60&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>79&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>84&lt;sup&gt;b&lt;/sup&gt;</td>
<td>78&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>51&lt;sup&gt;fgh&lt;/sup&gt;</td>
<td>76.80&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>5&lt;sup&gt;q&lt;/sup&gt;</td>
<td>3&lt;sup&gt;q&lt;/sup&gt;</td>
<td>9&lt;sup&gt;opq&lt;/sup&gt;</td>
<td>3&lt;sup&gt;q&lt;/sup&gt;</td>
<td>3&lt;sup&gt;q&lt;/sup&gt;</td>
<td>4.60&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall</td>
<td>35.43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.43&lt;sup&gt;e&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 27.86  Standard error = 2.35

LSD value at 0.05% for doses = 3.16
LSD value at 0.05% for insecticides= 2.67
LSD value at 0.05% for interaction = 7.06

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.5.24. Efficacy of botanical extracts against *Culex* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Chrysanthemum</th>
<th>Parthenium</th>
<th>Neem extract</th>
<th>Neem oil</th>
<th>Stevia extract</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>11&lt;sup&gt;qr&lt;/sup&gt;</td>
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<td>10&lt;sup&gt;qr&lt;/sup&gt;</td>
<td>13&lt;sup&gt;qf&lt;/sup&gt;</td>
<td>7&lt;sup&gt;qr&lt;/sup&gt;</td>
<td>10.60&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>21&lt;sup&gt;n0&lt;/sup&gt;</td>
<td>27&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>25&lt;sup&gt;mno&lt;/sup&gt;</td>
<td>32&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>19&lt;sup&gt;p0&lt;/sup&gt;</td>
<td>24.80&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>42&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>47&lt;sup&gt;jij&lt;/sup&gt;</td>
<td>52&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>42&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>35&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>43.60&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>3</td>
<td>54&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>66&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>64&lt;sup&gt;g&lt;/sup&gt;</td>
<td>73&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>40&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>59.40&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>64&lt;sup&gt;g&lt;/sup&gt;</td>
<td>84&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>79&lt;sup&gt;de&lt;/sup&gt;</td>
<td>88&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>50&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>73.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>87&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>92&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>55&lt;sup&gt;h&lt;/sup&gt;</td>
<td>84.80&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Control</td>
<td>9&lt;sup&gt;fr&lt;/sup&gt;</td>
<td>5&lt;sup&gt;f&lt;/sup&gt;</td>
<td>13&lt;sup&gt;p1&lt;/sup&gt;</td>
<td>6&lt;sup&gt;r&lt;/sup&gt;</td>
<td>6&lt;sup&gt;r&lt;/sup&gt;</td>
<td>7.80&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>Overall</td>
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<td>48.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.29&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

Standard deviation = 30.13 \hspace{1cm} Standard error = 2.55

LSD value at 0.05% for doses = 3.32

LSD value at 0.05% for insecticides = 2.80

LSD value at 0.05% for interaction = 7.41

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.5.25. Efficacy of botanical extracts against *Aedes* spp. 3rd instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 24hrs with</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chrysanthemum</td>
<td>Parthenium</td>
</tr>
<tr>
<td>0.5</td>
<td>17&lt;sup&gt;lmn&lt;/sup&gt;</td>
<td>24&lt;sup&gt;kl&lt;/sup&gt;</td>
</tr>
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<td>1</td>
<td>29&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>47&lt;sup&gt;hi&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>57&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>68&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>72&lt;sup&gt;d&lt;/sup&gt;</td>
<td>74&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>7&lt;sup&gt;o&lt;/sup&gt;</td>
<td>3&lt;sup&gt;o&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall</td>
<td>52.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>58.86&lt;sup&gt;a&lt;/sup&gt;</td>
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</tbody>
</table>

Standard deviation = 31.97  Standard error = 2.70
LSD value at 0.05% for doses = 3.39
LSD value at 0.05% for insecticides= 2.86
LSD value at 0.05% for interaction = 7.58

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.5.26. Efficacy of botanical extracts against *Aedes* spp. 3\textsuperscript{rd} instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Chrysanthemum</th>
<th>Parthenium</th>
<th>Neem extract</th>
<th>Neem oil</th>
<th>Stevia extract</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>22(^{l})</td>
<td>33(^{k})</td>
<td>19(^{lm})</td>
<td>24(^{l})</td>
<td>11(^{nop})</td>
<td>21.80(^{f})</td>
</tr>
<tr>
<td>1</td>
<td>37(^{jk})</td>
<td>54(^{i})</td>
<td>34(^{k})</td>
<td>42(^{j})</td>
<td>23(^{l})</td>
<td>38.00(^{e})</td>
</tr>
<tr>
<td>2</td>
<td>68(^{g})</td>
<td>77(^{f})</td>
<td>67(^{g})</td>
<td>58(^{hi})</td>
<td>38(^{jk})</td>
<td>61.60(^{d})</td>
</tr>
<tr>
<td>3</td>
<td>81(^{ef})</td>
<td>92(^{bcd})</td>
<td>81(^{ef})</td>
<td>86(^{de})</td>
<td>53(^{i})</td>
<td>78.60(^{e})</td>
</tr>
<tr>
<td>4</td>
<td>93(^{bc})</td>
<td>100(^{a})</td>
<td>92(^{bcd})</td>
<td>90(^{cd})</td>
<td>63(^{abh})</td>
<td>87.60(^{b})</td>
</tr>
<tr>
<td>5</td>
<td>100(^{a})</td>
<td>100(^{a})</td>
<td>96(^{abc})</td>
<td>97(^{ab})</td>
<td>67(^{g})</td>
<td>92.00(^{a})</td>
</tr>
<tr>
<td>Control</td>
<td>12(^{no})</td>
<td>5(^{p})</td>
<td>14(^{mm})</td>
<td>6(^{op})</td>
<td>6(^{op})</td>
<td>8.60(^{g})</td>
</tr>
<tr>
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<td>59.00(^{b})</td>
<td>65.86(^{a})</td>
<td>57.57(^{h})</td>
<td>57.57(^{b})</td>
<td>37.29(^{c})</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
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</table>

Standard deviation = 32.93  
Standard error = 2.78

LSD value at 0.05\% for doses = 2.94
LSD value at 0.05\% for insecticides = 2.44
LSD value at 0.05\% for interaction = 6.57

Means in columns/rows followed by similar letters are not significantly different at 0.05\% level of probability (LSD test).
Table 4.5.27. Efficacy of botanical extracts against *Aedes* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Chrysanthemum</th>
<th>Parthenium</th>
<th>Neem extract</th>
<th>Neem oil</th>
<th>Stevia extract</th>
<th>Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0.5</td>
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<td>11&lt;sup&gt;mno&lt;/sup&gt;</td>
<td>13&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>16&lt;sup&gt;lm&lt;/sup&gt;</td>
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<td>12.20&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>29&lt;sup&gt;ji&lt;/sup&gt;</td>
<td>20&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>33&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>15&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>24.60&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>53&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>55&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>48&lt;sup&gt;g&lt;/sup&gt;</td>
<td>26&lt;sup&gt;ik&lt;/sup&gt;</td>
<td>46.60&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>68&lt;sup&gt;e&lt;/sup&gt;</td>
<td>71&lt;sup&gt;de&lt;/sup&gt;</td>
<td>69&lt;sup&gt;e&lt;/sup&gt;</td>
<td>56&lt;sup&gt;f&lt;/sup&gt;</td>
<td>38&lt;sup&gt;h&lt;/sup&gt;</td>
<td>60.40&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>73&lt;sup&gt;de&lt;/sup&gt;</td>
<td>81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>77&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>48&lt;sup&gt;g&lt;/sup&gt;</td>
<td>72.20&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>93&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>91&lt;sup&gt;b&lt;/sup&gt;</td>
<td>81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>53&lt;sup&gt;fg&lt;/sup&gt;</td>
<td>83.60&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
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<td>3&lt;sup&gt;p&lt;/sup&gt;</td>
<td>11&lt;sup&gt;mno&lt;/sup&gt;</td>
<td>3&lt;sup&gt;p&lt;/sup&gt;</td>
<td>3&lt;sup&gt;p&lt;/sup&gt;</td>
<td>5.00&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>Overall Mean</td>
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<td>48.86&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>27.14&lt;sup&gt;c&lt;/sup&gt;</td>
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</tbody>
</table>

Standard deviation = 30.40       Standard error = 2.57

LSD value at 0.05% for doses = 3.04
LSD value at 0.05% for insecticides= 2.57
LSD value at 0.05% for interaction = 6.80

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.5.28. Efficacy of botanical extracts against *Aedes* spp. 4th instar larvae during 2011-2012.

<table>
<thead>
<tr>
<th>Dose (%)</th>
<th>Mortality (%) after 48 hrs with Mean Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chrysanthemum</td>
</tr>
<tr>
<td>0.5</td>
<td>19&lt;sup&gt;n0&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>34&lt;sup&gt;km&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>61&lt;sup&gt;ghi&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>79&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>88&lt;sup&gt;ad&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>97&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>12&lt;sup&gt;nq&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>55.71&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Standard deviation = 31.85  
Standard error = 2.69  
LSD value at 0.05% for doses = 3.06  
LSD value at 0.05% for insecticides = 2.54  
LSD value at 0.05% for interaction = 6.84  
Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.5.29. Comparative toxicity of different plant crude extracts against 3rd instar larvae of *Aedes albopictus* and *Culex quinquefasciatus* (24 hrs exposure).

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment</th>
<th>% Lethal dose concentration</th>
<th>Slope</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LC$_{50}$</td>
<td>95% CL</td>
<td>LC$_{90}$</td>
</tr>
<tr>
<td>Aedes</td>
<td>Chrysanthemum</td>
<td>1.505</td>
<td>0.956-1.808</td>
<td>2.624</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>1.024</td>
<td>0.502-1.3098</td>
<td>2.452</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.480</td>
<td>0.807-1.787</td>
<td>2.820</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.869</td>
<td>1.460-2.165</td>
<td>3.702</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.815</td>
<td>2.481-3.355</td>
<td>8.533</td>
</tr>
<tr>
<td>Culex</td>
<td>Chrysanthemum</td>
<td>1.595</td>
<td>1.262-1.874</td>
<td>4.140</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>1.446</td>
<td>0.999-1.709</td>
<td>2.343</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.538</td>
<td>1.208-1.778</td>
<td>3.203</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.919</td>
<td>1.453-2.198</td>
<td>3.222</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.882</td>
<td>2.532-3.484</td>
<td>8.335</td>
</tr>
</tbody>
</table>
Table 4.5.30. Comparative toxicity of plant crude extracts against 3rd instar larvae of *Aedes albopictus* and *Culex quinquefasciatus* (48 hrs exposure).

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment</th>
<th>% Lethal dose concentration</th>
<th>Slope</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LC$_{50}$</td>
<td>95%CL</td>
<td>LC$_{90}$</td>
</tr>
<tr>
<td><em>Aedes</em></td>
<td>Chrysanthemum</td>
<td>1.349</td>
<td>0.977-1.582</td>
<td>2.324</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>0.849</td>
<td>0.454-1.136</td>
<td>1.875</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.374</td>
<td>1.213-1.507</td>
<td>2.488</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.426</td>
<td>0.941-1.698</td>
<td>2.251</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.086</td>
<td>1.833-2.350</td>
<td>5.836</td>
</tr>
<tr>
<td><em>Culex</em></td>
<td>Chrysanthemum</td>
<td>1.657</td>
<td>1.131-1.969</td>
<td>3.063</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>0.967</td>
<td>0.521-1.266</td>
<td>2.085</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.067</td>
<td>0.489-1.392</td>
<td>2.211</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.482</td>
<td>1.059-1.747</td>
<td>2.708</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.662</td>
<td>2.316-3.186</td>
<td>8.480</td>
</tr>
</tbody>
</table>
Table 4.5.31. Comparative toxicity of plant crude extracts against 4th instar larvae of *Aedes albopictus* and *Culex quinquefasciatus* (24 hrs exposure).

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment</th>
<th>% Lethal dose concentration</th>
<th>Slope</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LC$_{50}$ 95%CL</td>
<td>LC$_{90}$ 95%CL</td>
<td></td>
</tr>
<tr>
<td><em>Aedes</em></td>
<td>Chrysanthemum</td>
<td>1.541 1.194-1.772</td>
<td>3.069 2.611-4.264</td>
<td>4.286±0.572</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>1.455 0.970-1.737</td>
<td>2.638 2.191-4.173</td>
<td>4.960±0.570</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.656 1.501-1.790</td>
<td>3.079 2.784-3.549</td>
<td>4.758±0.529</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.618 1.174-1.990</td>
<td>4.603 3.362-9.813</td>
<td>2.823±0.348</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.544 2.287-2.897</td>
<td>6.452 4.972-10.338</td>
<td>3.171±0.490</td>
</tr>
<tr>
<td><em>Culex</em></td>
<td>Chrysanthemum</td>
<td>1.595 1.262-1.874</td>
<td>4.140 3.251-6.676</td>
<td>3.094±0.369</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>1.446 0.999-1.709</td>
<td>2.343 1.982-3.397</td>
<td>6.113±0.657</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.538 1.208-1.778</td>
<td>3.203 2.667-4.620</td>
<td>4.021±0.465</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.919 1.453-2.198</td>
<td>3.222 2.716-5.263</td>
<td>5.691±0.757</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.882 2.532-3.484</td>
<td>8.335 5.902-16.513</td>
<td>2.779±0.483</td>
</tr>
</tbody>
</table>
Table 4.5.32. Comparative toxicity of plant crude extracts against 4th instar larvae of *Aedes albopictus* and *Culex quinquefasciatus* (48 hrs exposure).

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment</th>
<th>% Lethal dose concentration</th>
<th>Slope</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LC$_{50}$ 95%CL</td>
<td>LC$_{90}$ 95%CL</td>
<td></td>
</tr>
<tr>
<td><em>Aedes</em></td>
<td>Chrysanthemum</td>
<td>1.426 1.252-1.566</td>
<td>2.618 2.387-2.975</td>
<td>4.855±0.584</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>1.287 0.907-1.543</td>
<td>2.126 1.816-2.911</td>
<td>6.080±0.687</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.530 1.364-1.667</td>
<td>2.671 2.445-3.012</td>
<td>5.296±0.616</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.308 0.487-1.725</td>
<td>3.229 2.382-9.458</td>
<td>3.208±0.416</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.254 1.988-2.564</td>
<td>6.527 4.967-0.667</td>
<td>2.775±0.429</td>
</tr>
<tr>
<td><em>Culex</em></td>
<td>Chrysanthemum</td>
<td>1.941 1.552-2.265</td>
<td>3.968 3.156-6.956</td>
<td>4.127±0.546</td>
</tr>
<tr>
<td></td>
<td>Parthenium</td>
<td>1.543 1.006-1.863</td>
<td>2.882 2.371-5.089</td>
<td>4.821±0.606</td>
</tr>
<tr>
<td></td>
<td>Neem extract</td>
<td>1.619 1.460-1.757</td>
<td>3.143 2.825-3.655</td>
<td>4.447±0.492</td>
</tr>
<tr>
<td></td>
<td>Neem oil</td>
<td>1.562 0.774-1.882</td>
<td>3.080 2.467-7.443</td>
<td>4.269±0.618</td>
</tr>
<tr>
<td></td>
<td>Stevia extract</td>
<td>2.889 2.537-3.499</td>
<td>8.302 5.854-6.905</td>
<td>2.796±0.503</td>
</tr>
</tbody>
</table>
### 4.6 Effect of radiation on some biological parameters of mosquito species

The results in Table 4.6.1 showed that irradiation dose significantly affected *Culex spp.* adult emergence and caused significantly variable adult deformities. Adult emergence was highest (90.50%) with irradiation dose of Gy 60 and lowest (39.50%) with 100 Gy. Adult emergence was 72.50% in control. Generally, adult emergence increased with increase in radiation dose from 20 to 60 Gy, but decreased with the higher doses of 80 and 100 Gy. Adult deformities were significantly higher (25.25%) with irradiation dose of 100 Gy and lowest (1.75%) in control. Generally, adult deformities increased with increase in radiation dose.

The results in table 4.6.2 showed that irradiation dose significantly affected *Aedes spp.* adult emergence and caused significantly variable adult deformities. Adult emergence was significantly higher of 90.50 and 91.25% with irradiation dose of Gy 40 and Gy 60, respectively. It was lowest (49.75%) with 100 Gy. Adult emergence was 82.0% in control. Generally, adult emergence increased with increase in radiation dose from 20 to 60 Gy, but decreased with the higher doses of 80 and 100 Gy. *Aedes spp.* adult deformities were significantly higher (29.75%) with irradiation dose of 100 Gy and lowest (2.25%) in control. Generally, adult deformities increased with increase in radiation dose.

The results of the experiment on effect of irradiation on *Aedes spp.* fecundity, egg viability and No. of matings showed that irradiations dose significantly affected no. of mating, fecundity in adult females and hatching of eggs in *Aedes spp.* (Table 4.6.3). It was found that No. of matings in *Aedes spp* females were significantly higher in control (7.75 matings) and females treated with 40 Gy (7.00 matings). It was lowest in females (2.00 matings) treated with 80 Gy dose. Fecundity of *Aedes spp* females was significantly higher in control (126.0 eggs) and lowest (35.25 eggs) with radiation dose of 80 Gy. *Aedes spp.* egg hatching was significantly higher in control (87%) and lowest (0.25%) with radiation dose of 80 Gy. Generally, No. of mating, fecundity and egg hathing in *Aedes spp.* decreased with increase in radiation dose.
Table 4.6.1 Effect of radiation dose on *Culex* spp. adult emergence and adult deformities during 2011-2012.

<table>
<thead>
<tr>
<th>Radiation dose (Gy)</th>
<th>Effect of radiation dose on</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult emergence (%)</td>
<td>Adult deformities (%)</td>
</tr>
<tr>
<td>0 (control)</td>
<td>72.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.75&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>59.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.25&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>40</td>
<td>81.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.25&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>60</td>
<td>90.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.00&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>80</td>
<td>48.75&lt;sup&gt;e&lt;/sup&gt;</td>
<td>17.75&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>100</td>
<td>39.50&lt;sup&gt;f&lt;/sup&gt;</td>
<td>25.25&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>65.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LSD value at 0.05% for dose = 3.75
LSD value at 0.05% for effect = 2.16
LSD value at 0.05% for interaction = 5.30

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.6.2. Effect of radiation dose on *Aedes* spp. adult emergence and adult deformities during 2011-2012.

<table>
<thead>
<tr>
<th>Radiation dose (Gy)</th>
<th>Effect of radiation dose on</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult emergence (%)</td>
<td>Adult deformities (%)</td>
</tr>
<tr>
<td>0 (control)</td>
<td>82.00\textsuperscript{b}</td>
<td>2.25\textsuperscript{b}</td>
</tr>
<tr>
<td>20</td>
<td>65.50\textsuperscript{c}</td>
<td>5.75\textsuperscript{gh}</td>
</tr>
<tr>
<td>40</td>
<td>90.50\textsuperscript{a}</td>
<td>6.25\textsuperscript{gh}</td>
</tr>
<tr>
<td>60</td>
<td>91.25\textsuperscript{a}</td>
<td>8.25\textsuperscript{g}</td>
</tr>
<tr>
<td>80</td>
<td>62.50\textsuperscript{c}</td>
<td>21.75\textsuperscript{f}</td>
</tr>
<tr>
<td>100</td>
<td>49.75\textsuperscript{d}</td>
<td>29.75\textsuperscript{e}</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>73.58\textsuperscript{a}</td>
<td>12.33\textsuperscript{b}</td>
</tr>
</tbody>
</table>

LSD value at 0.05% for treatment = 3.18
LSD value at 0.05% for effect = 1.84
LSD value at 0.05% for interaction = 4.50

Means in columns/rows followed by similar letters are not significantly different at 0.05% level of probability (LSD test).
Table 4.6.3 Effect of irradiation on *Aedes* spp. (No. of mating, fecundity and egg hatching under No-choice test during 2011-2012)

<table>
<thead>
<tr>
<th>Radiation dose</th>
<th>No. of mating</th>
<th>Fecundity (No. of eggs/female)</th>
<th>Egg Hatching</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (control)</td>
<td>7.75&lt;sup&gt;a&lt;/sup&gt;</td>
<td>126.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>87&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>40</td>
<td>7.00&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>102.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>60</td>
<td>6.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>97.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.25&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>80</td>
<td>2.00&lt;sup&gt;c&lt;/sup&gt;</td>
<td>35.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.25&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD value at 0.05%</td>
<td>1.31</td>
<td>11.58</td>
<td>5.35</td>
</tr>
</tbody>
</table>

Means in columns followed by different letters are significantly different at 0.05% level of probability (LSD test).
V. DISCUSSION

5.1 Entomological surveillance

Peshawar valley comprising of four districts, namely Peshawar, Mardan, Nowshera and Charsadda is the hub for breeding of fresh and turbid water mosquitoes due to plenty of natural and artificial habitats in the area. The human overcrowding due to internal displacement from the Northern and Southern areas of this province caused by insecurity due to terrorism and poverty and devastated floods in the country have further promoted the potential for spread of vector born diseases and may lead to possible epidemics/outbreaks with high morbidity and mortality. These districts were therefore, focused mainly for the entomological surveillance to know the real status of general mosquitoes with special emphasis on Dengue vectors in these areas as a model for further studies and devising the vector management strategies under the international collaboration program of vector management.

Ever since dengue cases were diagnosed in 2007 (WHO, 2008) followed by the severe epidemic in 2011, 2012 in Lahore and in Swat during 2013, the local public health authorities (Malaria Control program) in collaboration with NGOs have been battling the vectors species by using insecticides and larvicides as the only tool for management presently in environmentally unsafe way. The important aspect of entomological surveillance, education and community involvement in the removal of artificial containers that serve as larval habitats is not properly utilized so far. The larval habitats are more common in these areas with increasing trend and therefore, the usual control movements may require redirecting their actions. In addition, the results shows that persistence of vectors is probably more associated with meteorological, cultural, behavioral and environmental conditions and larval indices are high enough to maintain disease transmission especially in the months of September - November.

According to current entomological survey, larval population of Culex spp. showed significant variations collected from various sites in a range of habitat types in Peshawar. Chitti and Pattamaporn, (2007) also used the same method of immature collection for entomological survey in the study area. Similarly, immature survey in different productive habitats across all the study sites was adopted by Lin et al., (2009) for vector surveillance. In our study, the population of larvae was highest at Ring Road
and Tarnab Colony where larvae were collected from sewage water habitat. The occurrence of this mosquito in Ring road was due to contaminated area around the city and in Tarnab Colony due to no proper drainage/sewage system. The physical and chemical examinations of the habitats were also conducted during the surveillance. It was observed that the sewage nature water habitat were comparatively with high turbidity, low dissolved oxygen and high temperature and high pH. The Culex spp. was mainly favored by these conditions in our results. Therefore, the sewage water habitats of Ring Road, Tarnab Colony, Kala Mandi-I and Hayatabad-I was the highly inhabited areas by Culex larvae. Similar correlation of Culex spp. with high turbidity, temperature and pH was established by Kiyoshi et al., (2002) when, they collected high population of Culex tritaeniorhynchus from hot, humid and turbid habitats of Karachi, Pakistan. Minimum larval population with low indices was recorded during December and January. This may be due to its negative correlation with low temperature. The peak abundance of Culex spp. was highest during September due to overlapping generations and favorable environmental conditions. However, the indices were relatively low in the month of July that may be due to high temperature based natural mortality of adults. Our results are in accordance to Petersen and Marfin, (2002), they identified peak incidences of Culex spp. related to west Nile virus in late summer, even though inception was observed from July to December during their surveillance study. McMahon et al., (2008) had also reported high population of Culex spp. for the late summer months.

Dengue, being a widespread mosquito-borne infection that is becoming a major health problem in Pakistan (Jahan, 2011), we emphasized on the prevailing conditions of Dengue vectors in the area by continuous larval/pupal collection during this study. Jayasooriyaa et al., (2009) determined Aedes aegypti and Aedes albopictus status for Dengue by immature surveys through larvae and pupae collection in different habitats. Tariq et al., (2010) reported that the entire 18 Towns of Karachi city were found positive for Dengue vector mosquitoes. They devised the control strategy based on the larval abundance in the respective habitats accordingly. We recorded the highest population of Aedes spp. in rural areas with more vegetations at NIFA-I and Muslim Town-II collected from irrigation channels and water tanks, while the semi-urban and urban areas like Tarnab Colony, Kala Mandi-I, Ring Road, Hayatabad-I, Bakhshupul, Bus Stop, Tahkal-I and Tahkal-II were the destructive places for Aedes spp. where no larvae were found. Out of these areas, some areas with rural nature and more vegetation were highly
polluted with no proper sewage system and habitat types were mainly of sewage water. Vezzani, (2006) reported that cemeteries with more natural vegetation were extremely proper habitats for artificial container-breeding mosquitoes due to easy accessibility to the required resources. Chadee, (2009) considered key premises of natural vegetation, human activities and key containers in dengue sero-prevalence. Our results highlight that *Aedes* spp. is rather more rural than urban, semi-urban areas contrary to Vincent *et al*., (1998), who reported the occurrence of *Aedes* spp. in close proximity to residences or workplaces of patients. However, Gratz, (2004) reported *Aedes albopictus* as a continuance vector of dengue in rural areas of dengue-prevalent countries. Mean maximum larval density was recorded from September to December; however, Aedes population was low from January to July. This species was found to prefer medium temperature and therefore the indices was high in September-December. Suleman *et al*., (1996) also reported that *Aedes* spp. population increased during late August; however, the application of insecticides reduced the abundance of species during its favorable months of October-November. The examination of widespread research indicates that *Aedes albopictus* most likely serves as an upholding vector of dengue virus especially in rural areas. The reason for high abundance of species in rural areas may be the favorable environment for protection from heat, prevalence of blood source of human and animal activities etc. may be the good indicators for peak population of these mosquitoes. These results are in agreement with that of Petersen and Marfin, (2002). McMahon *et al*., (2008) reported peak incidence of virus in late summer from the rural areas, although onset had occurred from July to December. However, Pages *et al*., (2006) are of the view that *Aedes albopictus* has extended to all continents with the ability to establish in most climates.

*Anopheles* species collected from various sites of Peshawar showed significant differences. All the studied sites except NIFA-I, Tarnab Farm, Kala Mandi-II and University of Agriculture, Peshawar (UAP) were the critical places for *An*. spp. where no larvae were found. The breeding of larvae was recorded in the habitats with specific chemical properties of medium pH, high level of dissolved oxygen and physical properties of low turbidity, shadowed places, the habitats with cemented or concrete bottom and presence of phyto-zooplankton in the habitats. Minakawa *et al*., (1999) characterized the aquatic habitats of anopheline and culicine on the basis of size, pH and distance to the human dwellings. They suggested the importance of detailed water
chemistry analysis in the spatial variation of anopheline larval distribution. Sharma and Hamzakoya, (2001) also recorded the breeding of An. stephensi from rain-harvesting cement storage tanks. The temperature 29±2°C from August to October also favored its peak activities in these months. Zaim et al., (1995) reported An. culifacies as the main vector of malaria in Baluchistan, southeastern Iran with populations peaked in April-May and again during August-November.

The insect population of Culex spp. showed significant variations collected from various sites in a range of habitat types in Nowshera. Larval density was highest at Pabbi-II and Taru-I accumulated from sewage water indicating the inhabited area of Culex larvae. The incidence of this specie in Taru and Pabbi may be due to infected irrigation water resulting in high breeding of the turbid sewage dwelling mosquitoes. Maximum larvae of Culex spp. were recorded during September. Larval hatching started in January, increased with season change up to May, decreased during June-July and reached to its peak stage in September.

Aedes spp. showed considerable disparity among different locations of Nowshera. Old Military Farm and New Military Farm were the important places where larvae were seen at nearby irrigation channels and water tanks for animal use. This may be due to the availability of animals as easily access able blood source in the dairy farms area. Vincent et al., (1998) in their field study, caught female adult Aedes aegypti and Aedes albopictus mosquitoes from selected dengue sensitive areas in Singapore and the geographic locations of these mosquitoes were correlated with the residences or workplaces of patients within dengue rash areas. Our results of high population of this specie near to animals dwelling were in accordance to Gratz, (2011). He documented the potential of Aedes albopictus in transmitting many arboviruses to laboratory animals and birds. In Americas wild-caught mosquitoes of this species were found positive for the dengue virus, also highlights its anthropophilic nature. The population recorded in our study was comparatively low to the Culex spp. but according to Gratz, (2011), Aedes albopictus continues to spread, replacing Aedes aegypti in various areas, and is becoming common. We therefore, fear the alarming successful establishment of this species in the area. The presence of primary dengue vectors (Aedes aegypti) in Landikotal and Peshawar previously reported by Suleman et al., 1996 were not
confirmed in our study. This may be due to the spreading nature of this species (*Aedes albopictus*) that might have replaced the primary vector (*Aedes aegypti*) as per Gratz, (2011) observations. Mean maximum larval density was recorded during October and November. The emergence of larvae was seen from January to May indicating low density during June-July but further increased in August till November. Suleman *et al*., (1996) observed peak population of *Aedes* spp. during late August.

*Anopheles* spp. showed significant differences collected from various sites of District Nowshera. Taru-I, Old Military Dairy Farm and New Military Dairy Farm were the major places where larvae were collected from water tanks and irrigation channels. Mean maximum larval density was recorded in October. Zaim *et al*., (1995) reported that *An. culicifacies* populations peaked in April-May and again during August-November. The population of *An.* spp. was low from January to July and December. The emergence of larvae from January to May and its increase in August till November may be due to positive situation for breeding of insect population. The prior researchers indicated that *Anopheles albimanus* larvae were most frequent at uncovered sites with abundant Culex larvae and grass at the edge of the water (Marten *et al*., 1996). Irrigation-based sites support the breeding of different anopheline vectors (Herrel *et al*., 2004). Blackwell and Johnson, (2000) found the largest numbers of *An. gambiae* larvae in small, shaded pools and rice fields. The breeding success of *Anopheles culicifacies* were reported to be positively related only to temperature and temporary stream bed pool habitats (Piyaratnea *et al*., 2005).

*Culex* spp. showed significant variations collected from various sites in Mardan. The mean larval population was highest at Locomotive Factory Residential Colony and College Chowk-I where larvae were collected from sewage water. Locomotive Factory Residential Colony, College Chowk-I, Toru and Rahimabad were the inhabited areas where *Culex* spp. were found in sewage water, irrigation channels and scrap material. The high population of *Culex* spp. in these urban areas was similar to the results of Jonathan *et al*., (2007). They showed the association of *Culex quinquefasciatus* and *Aedes aegypti* with high density in houses of urban and suburbs areas. The irrigation channels in the infected areas are well polluted with drainage water that resulted in peak density of Culex mosquitoes. Maximum larvae of *Culex* spp. were recorded during September. Larval hatching started in January; it increased with season change up to
May and decreased during June-July. The presence of *Culex* spp. in sewage water and irrigation channels may be the fact that surrounding of Mardan area has sympathetic atmosphere for breeding of Culex larvae. The present results are in conformity with that of some previous researchers, in that the inception had happened from July through December (Petersen and Marfin, 2002). *Culex poicilipes* was highly linked with more vegetation, while, *Culex annulioris* comparatively with clean water comprising surface vegetation, and *Culex quinquefasciatus* was more related with turbid and muddy water (Ephantus *et al.*, 2007; Muturi *et al.*, 2007).

Significant differences were seen among *Aedes* spp. abundance in Mardan area. The insect population was highest at Toru and Jalala where larvae were collected from fresh irrigation water and water accumulated in scarp materials. SCRI-I, Locomotive Factory Residential Colony, College Chowk-I and College Chowk-II were the places where no *Aedes* spp. larvae were found. All these sites provided inappropriate environment for breeding of *Aedes* spp. The highest density of larvae was recorded during November. Density of the larvae was lower from May – July, however it increased from August to November. The larval population of *An.* spp. from Rahim Abad and Nigar Bagh, in the vicinity of Mardan, were collected from irrigation channels, ponds and rain water. Minakawa *et al.*, (1999) found high number of mosquitoes in habitats having proper size, pH and adjacent to residences. Doherty, (2007) reported that agricultural areas had the highest mosquito abundance, likely due to increased irrigation. Maximum larval density was recorded in September whilst the population of *Aedes* spp. was low during all the study period.

The insect population of *Culex* spp. showed significant variations collected from various sites in Charsadda. Mean population of larvae was highest at Rajar and Sardaryab where larvae were collected from sewage water. Naguman, Sardaryab and Rajar were the inhabited areas in Charsadda where Culex larvae were found in ponds, pools and sewage water. Maximum larval density was recorded in September. The peak incidence of West Nile virus linked with *Culex spp.* was reported by Petersen and Marfin, (2002) in late summer (September). Larval abundance peaked during September while its abundance lowered in June-July. *Aedes* spp. collected from different places showed significant differences. Mean population of larvae was highest at Naguman and Sardaryab where larvae were collected from fresh water ponds and pools. Maximum
larval density was recorded during October-November however; June-July was the imperfect season for larval abundance. The larval population of *An.* spp. showed significant differences collected from different sites and habitat types. The mean population of larvae was highest at Naguman and Sardaryab where larvae were collected from water ponds and pools. Maximum larval population was recorded in September, however low density was recorded during June-July. The abundance of Culex in September and Aedes in November collected from ponds and sewage water may be due to presence of long irrigation system and larval breeding in August was due to the prevalent favorable environments for breeding of this species in the adjacent areas of Charsadda. Arthur *et al.*, (2003) determined that adults grouped strongly within houses. Doherty, (2007) reported that agricultural areas had the highest mosquito abundance, likely due to increased irrigation. McMahon *et al.*, (2008) observed the greatest number of *Culex tarsalis* in July and August. The breeding sites of *Aedes* spp. differed from one locality and time period to another one and irrigated fields and orchards were important determinants for the dengue disease (Kuslimawathie and Siyambalagoda, 2005; Sophie *et al.*, 2005).

The outcome of entomological surveillance showed highest larval population of Culex spp. collected from sewage water at Ring Road, Tarnab Colony, Hayatabad, Pabbi-II, Locomotive Factory Residential Colony and Rajar which are polluted and residential areas around the city. High temperature, pollution and turbidity involved in peak abundance of Culex spp. Mosquitoes proliferation started in January which peaked in September and gradually decreased till December. Highest *Aedes* spp. abundance was noted in irrigation channels at NIFA-I, Military Dairy Farm Khaishk, Toru, Naguman and Sardaryab. Poor drainage/irrigation system and dirty water implicated peak insect abundance of *Aedes* spp. The peak abundance of *Anopheles* spp. was noted in irrigation water at Kala Mandi-II, Taru-I and Rahimabad caused by dirty and polluted water. The species behavior opening in January varied in running season was the source of imminent damping period. The current results of rural nature of *Culex and Aedes* spp. were confirmed and identified by some previous researchers, where they have indicated that these mosquitoes are becoming major health problems in Pakistan (Tariq *et al.*, (2010; Jahan, 2011). Suleman *et al.*, (1996) reported that *Aedes* spp. population increased during August but decreased during October-November with insecticides application.
5.2 Indoor/outdoor ovitraps surveillance

Ovitrap monitoring is a helpful tool in any good vector control strategy as described by Gavaudan et al., (2011) and many other researchers. Scott and Morrison, (2010) had also reported on the importance of entomological thresholds of Mosquitoes species. Chen et al., (2006) indicated that ovitrap was a sensitive tool to attract gravid females of more than one mosquito’s species for ovi-position. They highlighted the importance of variation in vector mosquito’s populations in dengue surveillance and prevention program. In the current entomological surveillance through ovitraps, we exploited the need of blood source for mosquitoes and tested the hypothesis of their inhibition in the inhabiting areas and the nearby area having these requirements for the survival of their next generation. We conducted the ovitrap surveillance in indoor/outdoor points close to human and animal dwellings and considered the presence of vegetation for protection of mosquitoes in these sites. Significant differences were observed among the mosquito species found in the traps kept in indoor and outdoor locations.

The ovitrap surveillance results of indoor sites indicated that Culex species was more abundant than Aedes and Anopheles. More Culex spp. positive traps were found in indoor sites at Peshawar. The abundance of Culex and Anopheles peaked in September. The breeding of both species started in January, persisted up to May and then decreased during June-July but increased again during August-September. The peak population of species in September may be due to the optimum environmental conditions available for reproduction at this time of the year. Culex species dominated Aedes and Anopheles at indoor locations in Nowshera. Aedes spp. was found in the months of November and December only. This may be due to its tendency for resting and dwelling outside than inside and may come inside during the two months only for escaping the low temperature outside and also due to unavailability of protection measures outside during these cold months of the year. The breeding of Culex and Anopheles started at January and its abundance peaked in September. Aedes was also found in this vicinity during November-December. Highest abundance of the species in September-October might reflect its breeding in August. To hit the highest point of species in September-October seems to provide appropriate impression for species breeding in August. The mosquito species varied significantly collected from different indoor locations in Mardan. Culex
species dominated Anopheles and Aedes. Maximum larvae of *Culex* spp. were found at different indoor sites. Aedes prevailed in November - December in this district. Culex and Anopheles peaked in September. Culex appeared in January and Anopheles in April. Similarly, the mosquito species showed significant variations collected from different indoor sites in Charsadda. *Culex* spp. had higher population than other two species. Maximum number of Culex larvae was found at various indoor locations in Charsadda. Aedes population remained low in these sites. Culex and Anopheles peaked during August-September, which might be due to favorable environmental conditions prevailing during these months.

The results of outdoor ovitrap surveillance indicated significant differences among the various sites, where Culex spp. dominated Aedes and Anopheles collected from various outdoor sites in Peshawar. All the three species peaked in May and October. The mosquito species breeding started at January, reached to its peak during August to October. The results from outdoor sites in Nowshera also yielded significant differences among the mosquito species, where Aedes and Culex dominated Anopheles. The breeding of all the three species started in January and reached to its peak during August to October. Culex and Aedes were self-motivated species during May, September and October. At Mardan, mosquito species abundance varied significantly at the different sites. *Culex* dominated the other two species. Anopheles population remained low from April to December, whereas Culex and Aedes peaked in May. The mosquito species started activities in January, which fluctuated during the coming months of the year. The peak population of mosquitoes in September and October might be due to wet season prevailing during June-July. Aditya et al., (2006) reported significant differences in variation with time and statistics of Aedes and Culex. The present results revealed that *Culex* dominated Aedes and Anopheles at both the indoor and outdoor locations. However, *Aedes* population was higher at outdoor as compared to indoor sites. Our results are at par with those of some of earlier researchers, where they reported that the areas relatively close to hospitals are the major breeding sites of dengue bunch and vector populations (Ali et al., 2003). The low mosquito number inside may be
due to presence of resting and un-disturbing places provided by vegetations in outdoor locations only. Moreover, higher control measures are applied inside than outside, which might add to this population difference at inside and outside sites. According to Gavaudan et al., (2011) reduction in the weekly median of eggs laid in the ovitraps from 2008 to 2011 indicated the good performance of the vector control and a reduction in the related epidemics risk. Also, more chemicals are applied indoor as compared to outdoor, which might have reduced Aedes population indoor. Higher populations of Culex and Anopheles indoor and outdoor may also be due to development of resistance to public health insecticides used commonly. Hribar, (2007) reported *Culex quinquefasciatus* as the most frequently encountered species with variety of habitats and areas. The current results of rural nature of *Aedes spp.* were confirmed and identified by some previous researchers, where they have indicated that *Aedes albopictus* serve as a maintenance vector of dengue in areas of rural nature. Chen et al., (2005) indicated that *Aedes aegypti* and *Aedes albopictus* were breeding equally with success both at indoor and outdoor sites. While *Anopheles arabiensis* was the predominant species in habitats adjoining to dwellings (Minakawa et al., 1999). Kuslimawathie and Siyambalagoda, (2005) reported that breeding sites of *Aedes aegypti* and *Aedes albopictus* differed from one locality to another as well as from one time period to another. Doherty, (2007) reported that agricultural areas had the highest mosquito abundance, likely due to increased irrigation. Harding et al., (2007) found larvae in a large range of habitats but were predominantly abundant in artificial bodies of water like empty cemented water tanks. Jonathan et al., (2007) showed the association of *Aedes aegypti* with high density houses in urban areas and *Culex quinquefasciatus* with low density houses in suburbs. McMahon et al., (2008) determined the species composition of mosquitoes in tires having 95% of the larvae of *Culex tarsalis* with peak in July and August.

5.3 Assessment of insecticide resistance in mosquito field populations

Insecticides are the most useful method for management of mosquitoes since long. But the regular use of insecticides points the population to selection as well as subsistence of the competent that results in resistance development of high rate in insect populations (Naureen, 2007) therefore, it has become a serious concern in many groups of vector mosquitoes. The extended bare of mosquito populations to insecticides consequently leads to the appearance of cross resistant strains also. Resistance play a
significant role in any vector control program in addition to the knowledge of this status assists to control vector population. We tested the vulnerability of commonly used public health insecticides for working out the status of resistance level in the mosquito field strains collected from different sites. Significant differences in susceptibility were observed among field strains of *Culex* spp. collected from various sites using Chlorpyrifos insecticide. The *Culex* spp. collected from Tarnab Colony and Hayatabad showed low mortality as compared to other sites and thus high level of resistance as compared to 100% mortalities of susceptible laboratory strain. No resistance (100% mortality) was observed in adult mosquitoes collected from Azakhel Park and Sardaryab after 48 hours exposure period which was similar to laboratory susceptible strain (control). The amplified resistance in Tarnab Colony may be due to regular use of Agricultural chemicals in the nearby Agri-fields of Tarnab Farm. While Hayatabad being the hub of high up of the society is mainly kept de-pest by using pesticides in the area on regular basis by public health, which might be the reason for high level of resistance in *Culex* spp. Feng et al., (2006) reported high resistance to different insecticides against *Culex* spp. and *Aedes* spp. Tikar et al., (2011) found resistance to Chlorpyriphos in *An.* Spp. larvae. In contrast, Julia et al., (2008) reported that different pesticides showed lower activity against *Culex* spp. and *Aedes* spp. that may be due to difference in environmental conditions or localities.

Similarly, the field collected *Culex* spp. from various sites showed considerable variations in mortalities when treated with Lambdacyhalothrin insecticide. The mortality was low in the strains collected from Tarnab Colony and Taru Jabba and thus again these two strains were declared resistant to this chemical also. The highest mortality (100%) in adult mosquitoes collected from Azakhel Park and Sardaryab after 48 hours exposure period was comparable to laboratory susceptible strain (control) and thus were declared susceptible. Our results of the mix trend, i.e. susceptible/resistant strains were attributed to the frequent use of chemicals in these sites. Khan et al., (2011) also reported moderate to high level of resistance to insecticides against filed strains. They linked resistance in mosquitoes to the use of seepage of agro-chemicals from the nearby agri-fields. While, Jahan and Amna, (2012) reported 100% mortality in field collected larvae using different doses of insecticides.
Deltamethrin treatment yielded variable mortalities in adult females of *Culex* spp. collected from different sites, where mortalities were significantly lower in Tarnab Colony and Taru Jabba. Highest mortality (100%) occurred in adult mosquitoes collected from Azakhel Park and Sardaryab after 24 hours. In control highest mortalities were recorded in mosquitoes collected from all sites except Tarnab Colony and Taru Jabba after 48 hours exposure period. The results confirmed the resistance of *Culex* spp. to Deltamethrin. Tahir *et al*., (2009) reported high level of resistance against 5% Deltamethrin in *Culex* spp. Pradya *et al*., (2010) found that DDT resistant *Culex quinquefasciatus* was also slightly tolerant to deltamethrin and permethrin. However, Tikar *et al*., (2011) found adults of *An.* spp. susceptible to Deltamethrin.

The larvae of *Culex* mosquitoes collected from various sites showed considerable variations in mortalities where Temephos was used. Highest mortality (100%) was recorded in field strain collected from all sites except Tarnab Colony, Hayatabad and Taru Jabba after 48 hours exposure period, which was similar to control. Highest mortality in mosquitoes collected at Sardaryab indicated the presence of absolutely no selection pressure in this site as surely no insecticides has been used in this area. With the increase in Temephos exposure from 01 to 48 hour increase in mortalities from 20 to 100% were noted. Sharma *et al*., (2003) reported high degree of resistance in *Culex* spp and *An.* spp. to fenthion and temephos.

Chlorpyrifos treatment yielded variable mortalities in *Aedes* spp. and *Culex* spp. collected from various sites. The adult *Aedes* collected from NIFA, Tarnab showed low mortality, whereas highest mortality (100%) was recorded in adults collected from Military Farm Khaishk, Azakhel Park and Naguman after 24 and 48 hours exposure period, which was similar to control. It is evident that application of Chlorpyrifos requires more time to kill *Aedes* spp. that indicates its in-efficiency against the test insect. Feng *et al*., (2006) reported high resistance in *Culex* spp. and *Aedes* spp. to different insecticides. According to Naureen, (2007) regular use of pesticides may lead to the development of high rate of tolerance in *Aedes* spp. Moderate to high level of resistance to agrochemicals in Pakistani field populations of *Aedes albopictus* was reported for the first time by Khan *et al*., (2011).
Adult *Aedes* spp. collected from various sites showed considerable variations in mortalities against Lambdacyhalothrin. The adults showed medium mortality collected from Toru and SCRI. Highest mortalities (100%) were found in mosquitoes collected from Military Farm Khaishk, Azakhel Park and Naguman after 24 and 48 hours exposure period, which was similar to control. Highest mortality in *Aedes* spp., collected from the three sites, 24 hours after Lambdacyhalothrin treatment might be due to its high toxicity against it. Hidayati *et al.*, (2011) reported that *Aedes* spp. adults were highly resistant to DDT, moderately resistant to propoxur and tolerant to permethrin. Khan *et al.*, (2011) found moderate to high level of resistance in field populations of *Aedes albopictus* to insecticides in Pakistan. According to Thipwara *et al.*, (2011) *Aedes aegypti* adults were highly susceptible to permethrin, deltamethrin and lambdacyhalothrin.

Deltamethrin application yielded significantly different mortalities of *Aedes* spp. adult females collected from different sites. The adult mosquitoes collected from NIFA - Tarnab and Toru showed medium level of resistance. Highest mortality (100%) occurred in adult mosquitoes collected from Hayatabad, Military Farm Khaishk, Azakhel Park and Naguman after 24 and 48 hours exposure period, which was similar to control. With the increase in Deltamethrin exposure time from 01 to 48 hour mortality increased from 33.33 to 100%. Highest mortality in *Aedes* spp. caused by Deltamethrin after 24 hours exposure time might be due to its high toxicity against the test insect. Some earlier researchers had reported toxicity results contrary to the present one, e.g. Rapeeporn *et al.*, (2005) reported low levels of resistance in *Aedes* spp. against deltamethrin as compared to the susceptible strain. Kamgang *et al.*, (2011) found field *Aedes* spp. populations susceptible to deltamethrin. Marcombe *et al.*, (2011) observed high mortality rates of susceptible sentinel *Aedes* spp. treated with deltamethrin. Polson *et al.*, (2011) reported 80-98% resistance in *Aedes aegypti* to deltamethrin.

The larvae of *Aedes* spp. collected from various sites showed considerable variations in mortalities against Temephos. Highest mortalities (100%) were recorded in larvae collected from all sites except NIFA and Hayatabad after 24 and 48 hours exposure period, which were similar to control. Increase in mortalities from 37.50 to 100% occurred with the increase in Temephos exposure time from 01 to 48 hours. Higher mortalities (100%) in *Aedes* spp. collected from all sites except NIFA and
Hayatabad after 24 hours exposure of Temephos showed its high toxicity against the Aedes larvae. Jahan and Amna, (2012) reported 100% mortality in field collected Aedes spp. larvae using different doses of temephos after one hour exposure. Karen et al., (2012) reported 80-98% mortality in Temephos and fenthion against Aedes spp. It can be concluded that for an effective and long term mosquito management plan, accurate determination of resistance must be done in field populations of mosquitoes in all areas of Pakistan.

5.4 Efficacy of IGR’s against mosquito species

Insect Growth Regulators (IGRs) are special new class of insecticides that influence insect mortality and growth inhibition in an environmentally safe way. This new control strategy was utilized for the vector control and proved effective both in the laboratory and field conditions. In our study the value of LC$_{50}$ and LC$_{90}$ was found maximum for Methoprene indicating its low toxicity while the two formulations of Pyriproxyfen gave low values for these standards and thus exhibited high toxicity against Aedes and Culex groups of mosquitoes. Previous researchers have also successfully utilized IGRs for controlling mosquitoes using Pyriproxyfen and Methoprene. IGRs have also been used as mosquito growth suppressant. Pyriproxyfen has yielded high toxicity against Culex Quinquefasciatus and Aedes albopictus larvae. Pyriproxyfen has been estimated as more lethal than Methoprene showing toxicity against Aedes aegypti larvae. According to Ali et al., (1995) the IGRs showed exceptional activity. Pyriproxyfen (LC$_{90} = 0.000376$ ppm) was 2.23 and 21.5 times more toxic than diflubenzuron and methoprene, respectively. Their study showed 21.5 times higher toxicity of pyriproxyfen against Aedes albopictus than of S-methoprene, when using the technical grade of each IGR. Schaefer et al., (1988) found that pyriproxyfen with LC$_{50}$ and LC$_{90}$ values of 0.01 and 0.052 ppb against Aedes taeniorhynchus was indicative of the excellent activity of IGRs against this spp. The superior activity of S-3 1 183 (pyriproxyfen) over S-methoprene against An. quadririmaculatus was also reported by Estrada and Mulla, (1986). Thus Pyriproxyfen is highly IGR i.e. active against a wide variety of insects of public health importance including mosquitoes (Hirano et al., 1998). In our study the LC$_{50}$ (0.002-0.016 ppm) and LC$_{90}$ (0.008-0.115 ppm) values were comparatively higher that may be due to difference in grade and other unknown factors. However, the dose suggested by Lee, (2001) for successive control of
Aedes togoi for long-term was 0.05-0.1 mg/L of 0.5% pyriproxyfen granules, which was higher than our and many previous findings.

The cumulative emergence inhibition caused by IGRs at 0.001 to 0.005 ppm was also acceptable and was in accordance to the findings of Trayler, (1994). He reported that Pyriproxyfen at 0.01 ppm caused 90% inhibition of Chironomid polypedilum and reduced the emergence of said species. He further stated that Pyriproxyfen at 0.01 ppm significantly reduced the emergence of P. nubifer and Kiefferrulus intmincrus (Skuse) for 24 days. According to Kawada, (1993) 50% emergence inhibition of Aedes albopictus was caused by methoprene at 1.1 ppb, diflubenzuron at 0.3 ppb, and pyriproxyfen at 0.024 ppb. Nayar et al., (2002) reported that Pyriproxyfen as compared with S-methoprene caused high levels (>80-100%) of initial and residual emergence inhibitions of the tested Aedes spp. in the laboratory and field conditions as well. Our categorization of IGRs in terms of efficiency (Pyriproxyfen 10WDG > Pyriproxyfen 0.5G > Methoprene) was also comparable to that reported by Ali et al., (1995). They categorized the toxicity ranking of chemicals and microbial tested as IGRs > pyrethroids > OPs > microbials.

The present results revealed that Pyriproxyfen 1.0 WDG formulation was highly effective against the larval stages of Aedes albopictus and Culex spp. in the field conditions also. Pyriproxyfen 1.0 WDG treatment caused mortality, growth inhibition and adult emergence properties from 1-4 months period under field conditions. Vythilingam et al., (2005) reported that pyriproxyfen against Aedes aegypti at 0.01 and 0.02 mg provided 100% control for 4 months. Sihuincha et al., (2005) observed that pyriproxyfen prevented adult emergence at extremely low concentrations in the laboratory and field conditions. The decrease in the suppression of the laboratory strain after exposure in the field may be attributed to high and regular rainfall in the experimental sites that have caused the dilution in the treated concentration of IGRs in the habitats. However, these results were still acceptable up to 6 months period. Like previous reports of World Health Organization this groups of IGRs appeared to be environmentally safe as high activities of animals and human were observed in the experimental sites with no negative effect on them.
It can be concluded that IGRs, particularly the two formulations of Pyriproxyfen offer an excellent potential for the control of *Aedes albopictus* and *Culex* spp. but it require the attention of public health authorities for small scale as well as wide management of the mosquitoes in the target sites.

5.5 *Efficacy of Plant crude extracts (Phyto-chemicals) against mosquito species*

The use of plant extracts for insect control has a number of useful qualities as these are expansively more ecological, no risk to health and environment and rich storehouse of chemicals of different biological activities as well. The larvicidal potential of the crude extracts of these plants were compared with some commercially available larvicides in our current study. Previous researchers had also reported potential of some plant extracts in mosquito control program. Chansang *et al.*, (2005) reported that plants are the chemical factories and rich source of bioactive chemicals, some of which have pesticidal and even medicinal properties also. Rajkumar and Jebanesan, (2005) also proved that the leaf extract of *Centella asiatica* has larvicidal properties and is an inhibitor for adult emergence against *Culex quinquefasciatus*. Chowdhury *et al.*, (2008) reported that the extract of *Solanum xanthocarpum* was found to be toxic against the larvae of *A. stephensi*. Mandal, (2011) reported 100% protection from the bite of *Culex quinquefasciatus* mosquito due to the action of *Eucalyptus* and *A. indica* seed oil. Nathan *et al.*, (2007) reported that the leaf extracts of *Eucalyptus tereticornis* showed 99% mortality at 160 ppm against the larvae of *A. stephensi*. Rahuman *et al.*, (2008b) observed that petroleum ether extract of *Chrysanthemum colocynthis* was extremely vigorous against fourth-instars larvae of *Aedes aegypti*. Mohan *et al.*, (2008) reported high toxicity of similar nature of plant extract against *An. stephensi*. Similarly, Radhika *et al.*, (2012) also proved high larvicidal properties of hexane extracts from *Chrysanthemum sinensis* leaves against *Aedes* spp. after 24 h of exposure. Kumar *et al.*, (2012) confirmed the potential of celery seed oil as the prospective larvicidal, repellent and irritancy agent for the control and management of *Aedes aegypti* population. Choochote *et al.*, (2004) reported that the ethanol extracted *A. graveolens* possessed excellent larvicidal activity against fourth instars exhibiting LD<sub>50</sub> and LD<sub>95</sub> values of 81.0 and 176.8 mg/L, respectively.
Keeping in view the recent trend of mosquito control through various plant extracts in many regions of the world, we assessed the efficacy of crude extracts of some plant extracts against mosquito species *Aedes albopictus* and *Culex pipiens* etc., by estimating the differences in doses of extracts and exposure period against third and fourth instars after 24 and 48 hours.

### 5.5.1 Chrysanthemum extract

In the present study we applied different doses of Chrysanthemum extract against 3-4th instars larvae of *Culex* and *Aedes spp*. All the concentrations caused mortalities in the mosquito species. Mortality (%) increased with increase in dose from 0.5 to 3% and increase in exposure period from 24 to 48h. Efficacy of the chrysanthemum against mosquito species was comparable with the commonly used synthetic insecticide Temephos as reported by some earlier researchers also. Kamaraj *et al.*, (2009) found the methanol extract of *Chrysanthemum indicum* leaves against *Culex tritaeniorhynchus* with LC$_{50}$ value of 42.29 mg/ml after 24h. Ghosh *et al.*, (2012) reviewed the efficiency of different plant extracts including Chrysanthemum and found its successful case studies as reported by many other workers around the world. Rahuman *et al.*, (2008a) observed that the botanical larvicides can contribute remarkably to reduce the vector population of mosquitoes. According to Kumar and Maneemegalai, (2008) extracts of *L. camara* @ 1.0 mg/ml concentration resulted in maximum mortality in *Aedes aegyptii* exposed for 24h period. Similarly, the extracts of *Cassia nigricans*, *Jatropha curcas* and *Datura innoxia* exhibited 100% mortality in fourth instars larvae of *Ochlerotatus triseriatus* (Georges *et al.*, 2008). Govindarajan, (2009) reported that leaf extracts of *Cassia fistula* in different solvents yielded 100% mortality of *A. aegyptii*. Shawkat *et al.*, (2011) tested flowers extract of chrysanthemum against flour beetle *Tribolium castanum* and found high concentration (40%) caused higher mortality of 100% while lower concentrations from 20-30% gave lower mortalities from 60-77%. But in our study we found higher mosquito larval mortalities with the lower concentrations (0.5-3%).

### 5.5.2 Neem extracts

In our results, different neem extracts gave variable mortalities of third and fourth instars larvae of *Culex spp*. Maximum mortality was noted at higher concentration (3%) while minimum mortality with the lower concentration of 0.5%.
Also, mortalities were higher after 48h as compared to after 24h. Higher mortalities of third instars larvae of *Culex* spp. (95.5%) and fourth instar larvae of *Culex* spp. (88.5%) caused by higher concentration of neem extract (3%) were comparable with that achieved with Temephos (100%). Similarly, different extracts of Neem yielded significantly higher mortalities in 3rd & 4th instars larvae of *Aedes albopictus*, where mortalities increased with higher concentration (3%) of the neem and exposure time (48h). Application of Neem extracts gave 95.5% mortality in third instar and 94% mortality in 4th instar larvae of *Aedes albopictus*.

These present results are comparable to that reported by some earlier researchers. Padi and Acheampong (1999) found 3% concentration of Neem Azal against mosquito larvae under laboratory conditions. However, this dosage, according to them gave poor performance in the field. Achio *et al.*, (2012) characterized the pesticidal properties of extracts and powders prepared from different neem (*Azadirachta indica*) parts (seed, leaf, stem and root) against the *Macrotermes* spp., *Phaseouslus* spp., *Periplaneta* spp. and larvae of *Anopheles* spp., which are important pests of agricultural and public health sectors. The lethal effect was low (30-55% mortality) against *Anopheles* spp. under field conditions. However, they declared termites and the weevils to be more susceptible to the various extracts, compared to the cockroaches and mosquito larvae. Our results are also needed to be tested under field conditions. However, encouraging results were reported by Padi and Acheampong, (1999) through increasing the rate of applications as 2 times per week of the neem powder in the known breeding habitats of *Anopheles* larvae resulted in 49% fewer adult female of *Anopheles gambiae* in Banizoumbou, as compared with previous captures under similar conditions. Arunpandiyan, (2011) strongly favored the use of *A. indica* as environment safely but with toxic effect to insect pests. The aqueous crude neem leaf extract showed 30% and 70% mortality rate of *Culex* mosquitoes after 6 h and 12 h exposure, respectively under laboratory as well as field conditions. Mullai and Jebanesan, (2007) found that bioactive compound azadirachtin with complete ovicidal activity in the eggs of *Culex tarsalis* and *Culex quinquefasciatus*. The maximum protection was observed in methanolic and ethyl acetate extract with protection time of more than 3 h for *Cucurbita maxima* and *C. colocynthis*. Maharaj *et al.*, (2010) assessed the repellent activity by topical application of the test sample to the ventral surface of test rodents and subsequent
exposure of the treated area to unfed female mosquitoes. The crude extracts from ethno-medical plants were found to be effective with 80% repellency against *Culex* mosquitoes.

### 5.5.3 Parthenium extracts

Parthenium aqueous crude extracts (0.5-3%) were found highly effective against third instar larvae of *Culex* spp. and *Aedes* spp. Highest (100%) mortality was recorded with the higher concentration (3%) after 24-48 hour exposure period. Also, higher Parthenium extract concentration of 3% resulted in 84% mortality in fourth instar larvae of *Aedes albopictus*. Some earlier researchers have also reported efficacy of parthenium extracts against wide range of insect pests including mosquito spp. Tatiana *et al.*, (2005) reported high efficacy of Parthenium extract against *Leishmania amazonensis*. We recorded 100% mortality in mosquito species with the use of parthenium extracts, which were comparable to that reported by some earlier researchers. Mullai *et al.*, (2008) reported the effectiveness of benzene extract of *P. hysterophorus* leaves against *Aedes aegypti*. Ahmad *et al.*, (2011) found *Ginkgo biloba* and *P. hysterophorous* effective against the Anopheles larvae, where *P. hysterophorous* showed strongest anti-oxidative enzymes activity among the three plants extracts tested in two media. Kumar *et al.*, (2011) found *P. hysterophorus* leaf extract most effective oviposition deterrent against *Aedes aegypti*. The present of mortalities in 3rd instar larvae of *Aedes* and *Culex* were achieved with LC$_{50}$ (0.849-0.967%) and LC$_{90}$ (1.875-2.085%), respectively. Kumar *et al.*, (2012) found the hexane and petroleum ether extracts prepared from the stem of *P. hysterophorus* effective exhibiting LC$_{50}$ values of 379.76 and 438.57 mg/L, respectively. The slight difference in efficiency may be due to the crude nature of the parthenium extracts in our study. The recent results by Wasu *et al.*, (2013) also strongly supports our results. According to them *Parthenium* extract showed deformities in larval, pupal and adult stage against lepidopterous insect pest, i.e. *Spodoptera frugiperda* and found to be most effective against fall armyworm.

### 5.5.4 Stevia extracts

Our results revealed that Stevia extracts were less effective against third instar larvae of *Culex* spp. causing 55.5% mortality after maximum exposure period of 48 hours. The results showed that Stevia extracts had little effect (53% mortality) against
fourth instar larvae of *Culex* and *Aedes* spp. Ahmad *et al.*, (2011) reported that among the three plants extracts tested in two media, *Stevia rebaudiana* exhibited higher larvicidal activity with LC$_{50}$ after 24 hour exposure. Our results were in contrary to that of Ahmad *et al.*, (2011). They had found ethanol extract of this plant to be highly toxic against the larval stages of *Anopheles* spp. under laboratory conditions. This may be due to differences in mosquito species and its method of extraction from this exotic plant. According to Gleiser and Zygadlo, (2007) the essential oils of *Lippia turbinate* and *Lippia polystachya* exhibited LC$_{50}$ values of 74.9 and 121 mg/L, respectively against *Culex quinquefasciatus*. Saravanan *et al.*, (2007) reported 100% larval mortality at 1,000 ppm in whole plant petroleum ether extract of *C. colocynthis* against fourth instars larvae of *C. quinquefasciatus*. Tiwary *et al.*, (2007) reported that essential oil of *Zanthoxylum armatum* was effective against *Culex quinquefasciatus* with LC$_{50}$ and LC$_{95}$ values of 49 and 146 mg/L, respectively. Kananathasan *et al.*, (2008) found extract of *V. trifolia* with highest larvicidal activity with LC$_{50}$ value of 9.25 ppm against fourth-instar larvae of *Culex quinquefasciatus*. Rahuman *et al.*, (2008c) reported that *Jatropha curcas* and *Phyllanthus amarus* extracts showed LC$_{50}$ value of 8.79 and 90.92 ppm, respectively against *Aedes aegypti* and 1.34 and 113.40 ppm against *Culex quinquefasciatus*, respectively. However, use of sweet plant (*Stevia rebudiana*) as the plant based mosquito larvicide control cannot be recommended because of its poor efficiency in our trials.

### 5.5.5 Neem oil

Previous literature has vitally declared the use of extracts of oily nature as more effective in term of suffocating the mosquito’s larvae or keeping away their adults by repelling natures of various oils. Amer *et al.*, (2006a) reported the efficiency of plant extracts in oil forms as highly effective in suppressing the mosquito larval population. Similarly, Amer *et al.*, (2006b) determined the larvicidal effects of plant oil extracts against mosquito population. Siriporn and Soonwera, (2011) reported increase in the percentage repellency when the concentration of essential oils was increased. In contrast, biting rates decreased when the concentration of essential oils increased. Kumar *et al.*, (2012) found *Apium graveolens* oils with effective repellent activity showing 100% protection after exposure to 24 and 48 hours.
In our study, different concentrations of Neem oil gave significantly variable mortalities in third and fourth instars larvae of *Aedes* and *Culex spp.* Mortality in 3\(^{rd}\) and 4\(^{th}\) instars *Culex spp.* was highest with the application of 1ppm of Neem oil for 48 hour exposure, which causing 86% and 78% mortalities, respectively. Similarly, 1ppm applied against *Aedes albopictus* 3\(^{rd}\) and 4\(^{th}\) instars gave higher mortalities of 88% and 83.5%, respectively. Pitasawat *et al.*, (2007) found significant larvicidal activity of the volatile oils of *A. graveolens* against the two mosquito species, *Aedes aegypti* and *An. stephensi*. According to Kumar *et al.* (2011) the essential oil extracted from *Mentha piperita* possessed excellent larvicidal efficiency against dengue vector. Achio *et al.*, (2012) found oil extracted from the neem seed kernel in minimal lethal concentration with greater lethal properties against the insects, in all cases @ 0.50 % v/v. These oils were more effective against termites and the weevils by recording the total deaths within 2-5 minutes as compared to the cockroaches and the mosquito larvae where total deaths were experienced only after 30-90 minutes. Mandal, (2011) evaluated the repellent activity of *Eucalyptus* and *A. indica* seed oils against *Culex quinquefasciatus* mosquito. The test oils showed excellent repellent properties against *Culex quinquefasciatus*. *A. indica* seed oil provided 90.26% and 88.83% protection, and the *Eucalyptus* oil 93.37% and 92.04%, at concentrations of 50% and 100% (v/v), respectively, with the protection time up to 240 min. There was no bite within 120 min and 180 min, respectively, due to the action of *Eucalyptus* and *A. indica* seed oil, and thus 100% protection from the bite of *Culex quinquefasciatus* mosquito was achieved. Vatandoost and Vaziri, (2004) tested *A. indica* extract against mosquito larvae in Iran under laboratory and field conditions, where LC\(_{50}\) and LC\(_{90}\) values for Neem oil were 0.35 and 1.81 mg/L for *An. stephensi* and 0.69 and 3.18 mg/L for *Culex quinquefasciatus*. Mortality in the pupal stage was significantly higher than the other stages. In field trials, using recommended dosages of 1 and 2 L/hectare, mortality of *Anopheles spp.* larvae was also higher than *Culex spp.* Prevention of adult emergence and pupal mortality was the main activity of this compounds. The maximum time of efficacy was 7 days at the highest concentration (2 L/hectare). Thus our results after confirmation under field conditions can be best utilized in integrating with other IPM tactics of mosquito control in the areas close to human dwellings.
5.5.6 Overall Evaluation of Botanical Extracts

Vector control by attacking both larval habitats and adult mosquitoes remains the principal method for reducing risk of vector infection. Plants have developed protection mechanisms, such as repellents and even insecticidal effects, to defend themselves against insect attack. These effects provide potential natural alternative to the use of synthetic insecticides. Thus botanical extracts will continue to play an important role in suppressing vectors of deadly diseases including dengue epidemics.

The different botanical extracts, in various concentrations, yielded significant variable mortalities in 3rd and 4th instars larvae of *Aedes* and *Culex* spp. after 24-48 hours period, where Parthenium extract gave highest while Stevia extract lowest mortalities. Parthenium extract applied at the rate of 2-3% resulted in 100% mortalities. Parthenium extract proved superior to the other plant extracts against 3rd and 4th instars larvae of *Culex* spp. after 24-48 hours exposure period. The five tested plants, in terms of efficiency against 3-4 instars mosquito larvae can be ranked as Parthenium > Chrysanthemum > Neem extract > neem oil > Stevia. The present results are in conformity to that reported by some earlier researchers. Tatiana et al., (2005) found Parthenium extract effective against *Leishmania amazonensis*. Sathish and Maneemegalai, (2008) reported that the leaf and flower extracts of the weed *Lantana camara* and *Parthenium hysterophorous* exhibited larvicidal activity against third instar larvae of *Culex quinquefasciatus* with maximum mortality. Ahmad et al., (2011) reported that among the three plants extracts tested in two media, *P. hysterophorous* had the powerful anti-oxidative enzymes activity. In our trials the LC50 & LC90 values were found maximum for Stevia extract indicating its low toxicity while Parthenium extract gave minimum LC50 & LC90 values that exhibited high toxicity against the two mosquito species. According to Kumar et al., (2012) the hexane and petroleum ether extracts prepared from the stem of *P. hysterophorus* were found effective exhibiting LC50 values of 379.76 and 438.57 mg/L, respectively. Thus *P. hysterophorous*, after testing its efficiency under field conditions, might be recommended in any IPM program of mosquito in the province.
5.6 Determination of effective radiation dose for male sterility and its mating compatibility with wild females.

Application of Sterile Insect Technique (SIT) entails the mass production, sterilization and subsequent release of sterile male insects in to a target population in an integrated area wide management strategy of mosquitoes. The released males inseminate wild females with sterile sperm. The females subsequently fail to produce viable offspring leading to an overall size reduction of the target population. Over the years, SIT has proven to be a safe, eliminate or contain particular insect pest population thus sterilization by irradiation remains the most practical way of mosquitoes control. Effective optimum dose of radiation is required to produce potent males that are compatible for mating with wild females. We therefore, tested various radiation doses at the pupal stage of *Aedes* spp. and determination was made on effect of radiation doses on adult’s emergence. The results of the effect of radiation on the biological parameters of *Aedes* spp. and subsequent potency of irradiated males with wild females are discussed below.

*Culex* spp. and *Aedes* spp. pupae treated with different radiation doses resulted in significantly different adult emergence. Adult emergence was higher at 60 Gy, however emergence decreased at 100 Gy. Adult deformity was higher at higher dose of 100 Gy.

The experiment of irradiation of adult *Aedes albopictus* males and its subsequent mating with wild females under no choice test gave variable results, where number of mating decreased with increase in radiation doses. Lowest number of mating was recorded with 80 Gy radiation dose. *Aedes albopictus* fecundity decreased with increase in radiation doses. Maximum hatching was recorded in control. Michelle *et al.*, (2006) reported that irradiation of pupae, for all doses tested, had no effect on adult emergence and survival curves of males irradiated as pupae or adults were similar or even slightly higher than non-irradiated males. This may be due to differences in temperature or improper use of sterilization indicating no effect on adult emergence. In our results, 60 Gy dose was found optimum for the desired number of mating, no or very low fecundity and hatching and thus may be considered in the Sterile Insect Techniques (SIT) of *Aedes albopictus*. Michelle *et al.*, (2009) reported similar requirements for SIT of mosquitoes, they emphasized on the certain
level of stability between sterile males and wild females. The sterile males should be compatible in mating with wild female under field conditions.

The use of SIT as a mosquitoes control strategy has been reported by some earlier researchers. Benedict and Robinson, (2003) detailed the use SIT as a safe technique including of accumulation production, releases and subsequent mating aggressiveness with wild females. Dyck et al., (2005) reported that SIT is an insect pest control method with a great success against agricultural insect pests. Michelle et al., (2006) stated that SIT has confirmed to be a safe, effective and environmentally sound method to suppress, eradicate or contain pest populations. Bellini et al., (2007) declared Aedes Albopictus species as more suitable for application of the SIT because of its urban-related distribution, low active dispersal potential and low population density. Alphey et al., (2010) suggested that SIT is more useful in the situation of integrated multi-approaches control strategies and it may be very effective in reducing the number of insects.
VI. SUMMARY

Vector borne diseases are emerging threats in Pakistan and thus require particular attention. The recent spread warning of dengue vectors in Pakistan show the potential epidemics of these diseases in areas where the dengue vectors are present. The strengthened surveillance of important mosquito species such as *Culex*, *Aedes* and *Anopheles* is thus required regularly. This is mostly imperative in the current situation of environmental and climatic changes continuously in Peshawar valley and elsewhere that might let in increase of vector populations and thus disease transmission. Vaccine is not available for many vector-borne diseases and chemical control of vectors is not safe, so new environment friendly approaches are needed to reduce vector populations. Field surveillance program is the pre-requisite for vector management successfully. Knowledge gained through surveillance program can be used to determine important factors for predicting disease risk.

Studies explained in this research developed from mosquito survey and collections initiated in Peshawar division viz. Peshawar, Nowshera, Mardan and Charsadda were to investigate the abundance of vector groups including dengue during 2011-2012 for devising safe management strategy subsequently. Seasonal index of *Culex*, *Aedes* and *Anopheles* were examined. Data were collected from various breeding sites; irrigation channels, pools, river banks, different containers inside houses and lawns and potential breeding places like scrap materials, pot vases, etc. The surveillance data can be utilized for locating the isolated sites required for the SIT of vector species. These informations can be utilized as baseline data for launching SIT program of *Aedes albopictus* on pilot scale in collaboration with International Atomic Energy Agency (IAEA).

The present results showed that *Culex* spp. significantly varied in a range of habitat types at Peshawar. Maximum abundance of larvae was found in sewage water (731) at Ring Road. Maximum larvae (1011) of *Culex* spp. were recorded during September. High abundance of *Aedes* spp. (38) was found in irrigation channels at NIFA-I, while *Anopheles* spp. was found in irrigation water at Kala Mandi-II. Maximum larval density was recorded during August, September and October. The abundance of *Culex* spp. was highest (237) at Pabbi-II Nowshera collected from sewage water.
Maximum larvae (310) of *Culex* spp. were recorded during September. The high abundance of *Aedes* spp. (31) was found in irrigation channels at new Military Dairy Farm Khaishk. Maximum larval density was recorded during October and November, while *Anopheles* spp. (9) was found in irrigation water at Taru-I. Maximum larval density (11) was recorded during October. Maximum *Culex* spp. (270) was collected from sewage water at Locomotive Factory Residential Colony Mardan. This species was at peak stage during September. *Aedes* spp. collected from scrap materials showed highest abundance (90). Maximum larval density was recorded during November. The abundance of *Anopheles* spp. (10.3) was collected from irrigation channels at Rahimabad. The larval density was high (17) during September. *Culex* spp. showed highest abundance (240) collected from sewage water at Rajar Charsadda. Maximum larvae (515) of *Culex* spp. were recorded during September. *Aedes* spp. (27) were collected from ponds and pools of river water at Naguman. Maximum larval density was recorded during October and November. Mean monthly population of *Anopheles* spp. (50) was collected from ponds and pools at Naguman. Maximum larval density (64) was recorded during September.

The ovitrap surveillance indicated that *Culex* spp. abundance was high (9.38%) than the other two species at indoor sites in Peshawar. The abundance of Culex and Anophleles was at peak stage in September (13.5%) and October (10.0%), respectively. *Culex* spp. was higher in number than Aedes and Anopheles. Mean percent positive traps of *Culex* spp. 10.4% were found at different indoor locations in Nowshera. The mean abundance of Culex and Anopheles was at peak stage in September (13.2%). In Mardan, the abundance of *Culex* and *Anopheles* was at peak stage in September (13.7%). Various species of mosquitoes showed significant variations collected from different indoor sites in Charsadda. *Culex* spp. had the highest number of +ve traps (10.6%) than other two species. The abundance of Culex was at peak stage in September.

Various species collected from outdoor locations showed significant differences in abundance. *Culex* spp. had more mean number (32.3%) than the other species in Peshawar. Species composition of all the three genera was dynamic during May and October. In Nowshera, the mean abundance (26.8%) of all the three species was at peak stage in October. Significant disparity was seen at various species collected from outdoor locations in Mardan, where *Culex* spp. dominated (20.3%) the other two species. The
mean abundance (22.2%) of the species was at peak stage in May. Culex spp. was active from May to September. Culex spp. had the highest trap index (21%) than other two species in Charsadda. All the species had maximum activities during May, September and October.

Chlorpyrifos applied in different concentrations against adult mosquitoes of Culex spp. yielded variable mortalities. Mortality was higher (79.54%) after 48 hours exposure. Highest mortality (100%) and thus no signs of resistance were recorded in mosquitoes collected from Azakhel Park and Sardaryab. Lambdacyhalothrin gave variable mortalities in Culex spp. (41.95% and 46.94%) collected from Tarnab Colony and Taru Jabba, respectively that highlights symptoms of resistance. Mortality was higher (85.19%) after 48 hours exposure. Highest mortality (100%) was recorded in mosquitoes collected from Azakhel Park and Sardaryab. Deltamethrin yielded higher mortalities in Culex spp. (91.20%) after 48 hours exposure period. Highest mortality (100%) was recorded in adult mosquitoes collected from Azakhel Park and Sardaryab. The application of Temephos showed higher mortality (91.11%) after 48 hours exposure period. Highest mortality (100%) was recorded in adult mosquitoes collected from all sites except Tarnab Colony, Hayatabad and Taru Jabba. These three sites are important in term of sign resistance in the field strains.

Chlorpyrifos treatment caused variable mortalities in Aedes spp. adult mosquitoes. Percent mortality was higher 86.48% after 48 hours exposure. Highest percent mortality (100%) was recorded in adult mosquitoes collected from Military Farm Khaishk, Azakhel Park and Naguman after 24 and 48 hours exposure period. Aedes population showed higher mortality (93.70%) after 48 hours period. The application of Lambdacyhalothrin showed highest mortality (100%) in collection from military dairy farm Khaishk, Azakhel Park and Naguman. The application of Deltamethrin showed higher mortality (92.31%) after 48 hours exposure. Highest mortality (100%) was recorded in adult mosquitoes collected from Hayatabad, Military Farm Khaishk, Azakhel Park and Naguman after 24 and 48 hours exposure period. The application of Temephos showed higher mortality (90.93% and 97.31%) against Aedes spp. after 24 and 48 hours exposure period, respectively. Highest susceptibility (100%) was recorded against mosquitoes in all sites except NIFA and Hayatabad after 24 and 48 hours exposure period and thus shows sign of resistance in
these two areas that might be due to high selection pressure.

Methoprene tested in different concentrations (0.01 to 0.05) against *Culex spp.* caused variable mortalities, where mortalities increased with concentration from 7% to 40%, but inhibition decreased from 40% to 14%. Higher mortality (40%) and inhibition (40%) were seen at 0.05 and 0.01 ppm concentration of Methoprene, respectively. High malformation in the species (37%) was recorded at 0.05 ppm concentration. The application of Pyriproxyfen showed maximum mortality (67%) with 0.05 ppm, inhibition (54%) and deformity (22%) at 0.01 ppm. The application of Pyriproxyfen 1.0 WDG showed maximum mortality (87%) was recorded with 0.05 ppm. Higher inhibition (48%) and deformity (27%) was observed at 0.01 ppm concentration.

The application of Methoprene at 0.05 ppm showed maximum mortality (36%) and inhibition (58%) against *Aedes* spp. High deformity of mosquitoes (20%) was recorded at 0.02 ppm. The highest adult emergence (90%) of mosquitoes was noted in control. Pyriproxyfen 0.5 WDG showed maximum mortality (73%) with 0.05 ppm. Highest inhibition (63%) and deformity (18%) were recorded with 0.02 ppm. The highest emergence population (94%) of mosquitoes was noted in control treatment. Similarly, Pyriproxyfen 1.0 WDG showed maximum mortality (78%) with 0.05 ppm. The highest emergence (91%) of *Aedes* spp. was recorded in control.

The application of Pyriproxyfen 1.0 WDG showed medium mortality (50%) against *Culex* spp. after 01 month. However, the inhibition was higher (47%) after 3 and 4 month duration. Maximum deformed larvae were seen after 3 months duration. Highest emergence (88%) was observed in control. Pyriproxyfen 1.0 WDG showed maximum mortality (46%) against *Aedes* spp. after 01 month; however inhibition was higher (58%) after 4 month duration. Higher deformed larvae (19%) were seen after 2 months. Emergence was highest (93%) in control treatment. The IGRs were ranked in terms of the tested parameters in the order of Pyriproxyfen 1.0 WDG > Pyriproxyfen 0.5 WDG > Methoprene.

The application of 3% Chrysanthemum extracts against *Culex* spp. showed highest mortality (96%) after 48 hour exposure. The same dose of extract showed
100% mortality against *Aedes* spp. after 24 and 48 hour exposure period. The extract applied against fourth instar larvae of *Aedes* spp. gave highest mortality (97%) at 3% extract after 48 hours. Highest mortality (98%) against *Culex* spp. was recorded by use of 3% neem extract after 48 hour exposure. The same extract applied against third instar larvae of *Aedes* spp. showed 96% mortality after 48 hour exposure period. Similar results (97%) were obtained when 3% neem extract was applied against *Aedes* spp. fourth instar larvae after 48 hour exposure period. Parthenium extract (3%) applied against the third instar larvae of *Culex* spp. showed highest mortality (100%) after 24 and 48 hours. Variable results were found with treatment of fourth instar larvae of the same species with the extract. Highest mortality (97%) was recorded with 3% extract after 48 hour exposure. The applications of 3% Parthenium extract showed 100% mortality against third and fourth instar larvae of *Aedes* spp. after 24 and 48 hour exposure period. Application of 3% Stevia extract showed medium mortality (58% and 55%) against third and fourth instar larvae of *Culex* spp. after 48 hour exposure. Application of the extract resulted in variable mortalities in third instar larvae of *Aedes* spp. *also*, where 58% mortality was achieved with the use of 3% extract after 48 hour exposure period. Stevia extract applied at the rate of 3% showed 55% resistance against fourth instar larvae of *Aedes* spp. after 48 hour exposure period. The application of 1ppm Neem oil showed highest mortality (94%) against third instar larvae of *Culex* spp. after 48 hour exposure. Neem oil at 1ppm gave highest morality (97%) against third instar larvae and 90% against fourth instar larvae of *Aedes* spp. after 48 hour exposure period.

The overall doses of phyto-chemicals resulted variances against 3rd instar larvae of *Culex* spp. after 24 and 48 hours period. Parthenium extract applied at the rate of 3% showed 100% mortality. Parthenium extract (3%) applied against fourth instar larvae of *Culex* spp. showed 92% and 97% mortality after 24 and 48 hours exposure period, respectively. In general, Chrysanthemum and Parthenium extracts applied at the rate of 3% each against *Culex* and *Aedes* spp. gave 100% mortality and Parthenium extract was the best control agent against 3rd and 4th instars larvae of these two groups after 24-48 hours period.

The different irradiation doses showed significant differences against *Culex* spp. The highest emergence of 90.50% was achieved with radiation dose of 60 Gy and...
highest deformity of 25.25% was noted with 100 Gy. *Aedes* spp. showed highest emergence (91.25%) and deformity (29.75%) with 60 Gy and 100 Gy dose of radiation, respectively. The mating frequency was acceptable at optimum doses of 40-60 Gy radiation.
VII. CONCLUSION AND RECOMMENDATIONS

Conclusion

- *Culex* spp. was abundant throughout Peshawar division.
- *Culex quinquefasciatus* was found as dominant species with wide range of habitats and its population’s index was high at both indoor and outdoor locations.
- *Culex tritaeniorhynchus* Giles was the second important species.
- *Culex* and *Aedes* activities peaked during August to November.
- *Aedes albopictus* was found as the only potential dengue vector in the study sites.
- *Aedes albopictus* was high at outdoor as compared to indoor locations.
- No evidence of the presence of the principal known vector of dengue (*Aedes aegypti*) was found in Peshawar valley.
- Sewage water and irrigation channels were the important habitat types for *Culex* breeding throughout the study area.
- *Aedes albopictus* was collected from scarp materials, fresh water sources and rural areas with high vegetation and near blood sources (human and animals dwellings) and *An.* spp. was recorded mostly from ponds, pools and irrigation channels.
- *Anopheles stephensi* Liston was abundant than *Anopheles culicifacies* Giles.
- The surveillance results were utilized for locating the isolated sites required for the SIT of vector species.
- High susceptibility (100% mortality) of the mosquito species were noted in some areas with low selection pressure like Sardaryab, Naguman, and Azakhel Park treated with Chlorpyriphos, Lymbdacyhalothrin, Deltamethrin and Temephos.
- *Culex* spp. and *Aedes* spp. collected from sites in regular exposure of Agro/public health chemicals possessed low to medium level resistant to insecticides.
- The 3rd instar larvae of mosquito species showed varied mortalities to different IGRs.
- The IGRs exhibited significantly high toxicity with LC$_{50}$ (0.002 to 0.016ppm),
LC$_{90}$ (0.008 to 0.115ppm) against the 3$^{rd}$ instars larvae of Aedes and Culex spp.

- The IGRs were classified in term of the tested parameters in order of Pyriproxyfen 1.0 WDG > Pyriproxyfen 0.5WDG > Methoprene.
- IGRs caused high mortalities of 50% in Culex spp. and 46% in Aedes spp. after 01 month in field collected populations.
- Four months after treatment, despite constant dilution of these habitats due to natural rainfall and despite the disturbances by animals activities, water sampled from these sources continued to be lethal to larvae and pupae.
- Different IGRs applied at the rate of 0.05 ppm resulted in high emergence inhibition of 99.5% in Culex spp. and 93.29% in Aedes spp.
- Among the phyto-chemical treatments, Chrysanthemum and Parthenium extracts were found the best control agents against 3$^{rd}$ instar larvae of Aedes spp. after 24 hours period.
- Parthenium and Chrysanthemum extracts applied at the rate of 3% against Culex Spp. and Aedes spp. showed highest percent mortality after 48 hour exposure period.
- The LC$_{50}$ & LC$_{90}$ values were found maximum for Stevia extract indicating its low toxicity while Parthenium extract gave minimum LC$_{50}$ & LC$_{90}$ values that exhibited high toxicity against the two mosquito species.
- On the basis of toxicity the phytochemicals were classified as Parthenium > Chrysanthemum > Neem extract and Neem oil > Stevia extract.
- The radiation dose of 100 Gy yielded lowest adult emergence and highest deformity in the mosquito’s species.
- The dose of 40-60 Gy was determined as the optimum dose for initiation male sterility required for SIT program.
- The sterile males at these optimum doses were found potent and compatible in mating with the wild females.
- These informations were utilized as baseline data for launching SIT program of Aedes albopictus on pilot scale in collaboration with International Atomic Energy Agency (IAEA) and Coordinated Research Project (CRP) was therefore, awarded by IAEA regarding the SIT of Aedes albopictus.
Recommendations

- On the basis of the present results it can be recommended that:
- Serological surveillance should be a necessary component of all dengue interventions and a standard entomological index should be utilized in all such studies.
- Serological surveillance of the wild strains of *Aedes albopictus* need to be assessed using RT-PCR methods for confirmation of vector capacity.
- Prospect research should be conducted using habitat management as reduction of source.
- Sewage water, scarp materials, ponds, pools and presence of water in containers are the most important breeding sites of mosquitoes, so these be eliminated/modified/treated.
- Source reduction is an effective way by removal of artificial and natural containers or alteration of breeding sites in and around living or working areas should be taken into consideration for devising interventions.
- Involvement of community to manage the populations of many kinds of mosquitoes.
- Media and print also play an important role in vector control.
- Research on the mechanism involved in the resistance of the vector strains to various agrochemicals should be studied at molecular level.
- Genetic bar coding is the new area of research to be explored in the identification of vector species.

To the author’s information, there have been no previous published studies on entomological surveillance, relative abundance of mosquitoes breeding close to residential sites and their environment friendly management in Pakistan.
LITERATURE CITED


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### APPENDICES

Table 1 Analysis of variance for *Culex* spp. collected from various sites in Peshawar.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>15</td>
<td>46941157.41</td>
<td>3129410.59</td>
<td>24244.96</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>49107243.01</td>
<td>4464294.81</td>
<td>34586.92</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>165</td>
<td>79843482.20</td>
<td>483899.99</td>
<td>3749.99</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>384</td>
<td>49564.66</td>
<td>129.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>575</td>
<td>175941447.30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 4.74%

Table 2 Analysis of variance for *Aedes* spp. collected from various sites in Peshawar.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>15</td>
<td>77041.23</td>
<td>5136.08</td>
<td>12326.59</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>52879.92</td>
<td>4807.26</td>
<td>11537.43</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>165</td>
<td>182789.32</td>
<td>1107.81</td>
<td>2658.75</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>384</td>
<td>160.00</td>
<td>0.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>575</td>
<td>312870.48</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 7.52%
Table 3 Analysis of variance for *Anopheles* spp. collected from various sites in Peshawar.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>15</td>
<td>12166.50</td>
<td>811.10</td>
<td>4719.12</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>3109.62</td>
<td>282.69</td>
<td>1644.76</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>165</td>
<td>11920.87</td>
<td>72.24</td>
<td>420.35</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>384</td>
<td>66.00</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>575</td>
<td>27263.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>16.31%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Analysis of variance for *Culex* spp. collected from various sites in Nowshera.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>10</td>
<td>3149710.13</td>
<td>314971.01</td>
<td>133256.96</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>3675217.34</td>
<td>334110.66</td>
<td>141354.51</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>110</td>
<td>5768930.40</td>
<td>52444.82</td>
<td>22188.19</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>265</td>
<td>624.00</td>
<td>2.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>395</td>
<td>12594481.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>1.88%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5 Analysis of variance for *Aedes* spp. collected from various sites in Nowshera.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>10</td>
<td>38096.00</td>
<td>3809.60</td>
<td>6058.64</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>31988.79</td>
<td>2908.07</td>
<td>4624.88</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>110</td>
<td>41631.45</td>
<td>378.46</td>
<td>601.90</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>265</td>
<td>166.00</td>
<td>0.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>395</td>
<td>111882.25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 8.57%

Table 6 Analysis of variance for *Anopheles* spp. collected from various sites in Nowshera.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>10</td>
<td>5605.54</td>
<td>560.55</td>
<td>1849.83</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>3770.97</td>
<td>342.81</td>
<td>1131.29</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>110</td>
<td>5816.27</td>
<td>52.87</td>
<td>174.48</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>265</td>
<td>80.00</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>395</td>
<td>15272.79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 16.40%
Table 7 Analysis of variance for *Culex* spp. collected from various sites in Mardan.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>9</td>
<td>2400281.50</td>
<td>266697.94</td>
<td>78248.78</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>4558396.70</td>
<td>414399.70</td>
<td>121584.26</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>99</td>
<td>4237697.30</td>
<td>42805.02</td>
<td>12558.93</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>240</td>
<td>818.00</td>
<td>3.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>359</td>
<td>11197193.50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 1.90%

Table 8 Analysis of variance for *Aedes* spp. collected from various sites in Mardan.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>9</td>
<td>284230.40</td>
<td>31581.15</td>
<td>42108.20</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>214650.90</td>
<td>19513.71</td>
<td>26018.29</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>99</td>
<td>365008.60</td>
<td>3686.95</td>
<td>4915.94</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>240</td>
<td>180.00</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>359</td>
<td>864069.90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 3.87%
Table 9 Analysis of variance for *Anopheles* spp. collected from various sites in Mardan.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>9</td>
<td>8080.53</td>
<td>897.84</td>
<td>1857.59</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>6367.47</td>
<td>578.86</td>
<td>1197.64</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>99</td>
<td>8002.77</td>
<td>80.84</td>
<td>167.25</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>240</td>
<td>116.00</td>
<td>0.48</td>
<td></td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>359</strong></td>
<td><strong>22566.77</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 14.82%

Table 10 Analysis of variance for *Culex* spp. collected from various sites in Charsadda.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>6</td>
<td>2497419.43</td>
<td>416236.57</td>
<td>122251.30</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>5976350.68</td>
<td>543304.61</td>
<td>159571.98</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>66</td>
<td>4933826.57</td>
<td>74754.95</td>
<td>21955.99</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>168</td>
<td>572.00</td>
<td>3.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>251</strong></td>
<td><strong>13408168.68</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 1.56%
Table 11 Analysis of variance for *Aedes* spp. collected from various sites in Charsadda.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>6</td>
<td>29521.21</td>
<td>4920.20</td>
<td>7653.64</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>28409.43</td>
<td>2582.67</td>
<td>4017.49</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>66</td>
<td>17187.07</td>
<td>260.41</td>
<td>405.08</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>168</td>
<td>108.00</td>
<td>0.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>251</td>
<td>75225.71</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 6.21%

Table 12 Analysis of variance for *Anopheles* spp. collected from various sites in Charsadda.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>6</td>
<td>93697.35</td>
<td>15616.22</td>
<td>26235.26</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>94286.85</td>
<td>8571.53</td>
<td>14400.17</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x M</td>
<td>66</td>
<td>203776.64</td>
<td>3087.52</td>
<td>5187.04</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>168</td>
<td>100.00</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>251</td>
<td>391860.85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 5.33%
Table 13 Analysis of variance for indoor ovitraps index of mosquito species in Peshawar

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>1455.01</td>
<td>727.50</td>
<td>2170.48</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>1656.15</td>
<td>150.55</td>
<td>449.18</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>1201.62</td>
<td>54.61</td>
<td>162.95</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>24.13</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>4336.91</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 12.23%

Table 14 Analysis of variance for indoor ovitraps index of mosquito species in Nowshera.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>1865.93</td>
<td>932.96</td>
<td>4408.00</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>1455.28</td>
<td>132.29</td>
<td>625.07</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>1334.47</td>
<td>60.65</td>
<td>286.59</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>15.23</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>4670.92</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 9.61%
Table 15 Analysis of variance for indoor ovitraps index of mosquito species in Mardan.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>5232.65</td>
<td>2616.32</td>
<td>8311.36</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>1432.72</td>
<td>130.24</td>
<td>413.76</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>1864.05</td>
<td>84.73</td>
<td>269.16</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>22.67</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>8552.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 8.90%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 16 Analysis of variance for indoor ovitraps index of mosquito species in Charsadda.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>1922.39</td>
<td>961.19</td>
<td>1664.89</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>1878.08</td>
<td>170.73</td>
<td>295.73</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>1346.44</td>
<td>61.20</td>
<td>106.00</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>41.57</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>5188.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 12.99%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 17 Analysis of variance for outdoor ovitraps index of mosquito species in Peshawar

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>13806.92</td>
<td>6903.46</td>
<td>4740.77</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>10877.78</td>
<td>988.88</td>
<td>679.09</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>8301.80</td>
<td>377.35</td>
<td>259.13</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>104.84</td>
<td>1.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>107</strong></td>
<td><strong>33091.34</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 6.78%

Table 18 Analysis of variance for outdoor ovitraps index of mosquito species in Nowshera.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>5639.78</td>
<td>2819.89</td>
<td>3885.60</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>8920.32</td>
<td>810.93</td>
<td>1117.41</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>5875.79</td>
<td>267.08</td>
<td>368.01</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>52.25</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>107</strong></td>
<td><strong>20488.14</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 6.13%
Table 19 Analysis of variance for outdoor ovitraps index of mosquito species in Mardan.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>5674.08</td>
<td>2837.04</td>
<td>3795.69</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>4529.87</td>
<td>411.80</td>
<td>550.95</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>4845.10</td>
<td>220.23</td>
<td>294.64</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>53.82</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>15102.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 7.93%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 20 Analysis of variance for outdoor ovitraps index of mosquito species in Charsadda.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specie (S)</td>
<td>2</td>
<td>3172.07</td>
<td>1586.03</td>
<td>1087.14</td>
<td>0.0000</td>
</tr>
<tr>
<td>Month (M)</td>
<td>11</td>
<td>9925.45</td>
<td>902.31</td>
<td>618.48</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x M</td>
<td>22</td>
<td>4808.72</td>
<td>218.57</td>
<td>149.82</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>105.04</td>
<td>1.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>18011.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 8.65%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 21 Analysis of variance for Chlorpyrifos insecticide against adult female mosquitoes of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>37246.36</td>
<td>4655.79</td>
<td>241.55</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>49490.62</td>
<td>24745.31</td>
<td>1283.87</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>2742.69</td>
<td>171.41</td>
<td>8.89</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>1561.19</td>
<td>19.27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total                         107    91040.86

Coefficient of variation = 7.72%

Table 22 Analysis of variance for Lambdacyhalothrin insecticide against adult female mosquitoes of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>29763.10</td>
<td>3720.38</td>
<td>317.06</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>36807.23</td>
<td>18403.61</td>
<td>1568.43</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>2634.35</td>
<td>164.64</td>
<td>14.03</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>950.43</td>
<td>11.73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total                         107    70155.11

Coefficient of variation = 5.23%
Table 23 Analysis of variance for Deltamethrin insecticide against adult female mosquitoes of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>33303.11</td>
<td>4162.88</td>
<td>758.75</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>39738.98</td>
<td>19869.49</td>
<td>3621.52</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>3943.01</td>
<td>246.43</td>
<td>44.91</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>444.40</td>
<td>5.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>77429.50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 3.23%

Table 24 Analysis of variance for Temephos insecticide against adult female mosquitoes of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>21705.44</td>
<td>2713.18</td>
<td>130.31</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>39001.92</td>
<td>19500.95</td>
<td>936.66</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>5182.71</td>
<td>323.91</td>
<td>15.55</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>1686.39</td>
<td>20.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>67576.46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 6.49%
Table 25 Analysis of variance for Chlorpyrifos insecticide against adult female mosquitoes of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>23717.86</td>
<td>2964.73</td>
<td>164.67</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>33623.61</td>
<td>16811.80</td>
<td>933.78</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>4035.64</td>
<td>252.22</td>
<td>14.00</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>1458.32</td>
<td>18.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>62835.43</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 6.14%

Table 26 Analysis of variance for Lambdacyhalothrin insecticide against adult female mosquitoes of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>12184.58</td>
<td>1523.07</td>
<td>158.61</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>37298.16</td>
<td>18649.08</td>
<td>1942.18</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>4434.15</td>
<td>277.13</td>
<td>28.86</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>777.77</td>
<td>9.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>54694.66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 4.17%
Table 27 Analysis of variance for Deltamethrin insecticide against adult female mosquitoes of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>19461.12</td>
<td>2432.64</td>
<td>361.88</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>33146.30</td>
<td>16573.14</td>
<td>2465.47</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>5137.29</td>
<td>321.08</td>
<td>47.76</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>544.49</td>
<td>6.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>58289.20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 3.48%

Table 28 Analysis of variance for Temephos insecticide against adult female mosquitoes of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site (S)</td>
<td>8</td>
<td>8661.68</td>
<td>1082.71</td>
<td>137.86</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>2</td>
<td>45511.59</td>
<td>22755.79</td>
<td>2897.50</td>
<td>0.0000</td>
</tr>
<tr>
<td>S x D</td>
<td>16</td>
<td>5859.74</td>
<td>366.23</td>
<td>46.63</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>636.14</td>
<td>7.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>60669.15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 3.52%
Table 29 Analysis of variance for Methoprene on mortality, inhibition, deformity and emergence of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>84.00</td>
<td>16.80</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>747.33</td>
<td>249.11</td>
<td>8.73</td>
<td>0.0001</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>32378.66</td>
<td>2158.57</td>
<td>75.66</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>2054.00</td>
<td>28.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>35264.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 21.15%

Table 30 Analysis of variance for Pyriproxyfen 0.5WDG on mortality, inhibition, deformity and emergence of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>76.30</td>
<td>15.26</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>7901.62</td>
<td>2633.87</td>
<td>124.04</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>43135.57</td>
<td>2875.70</td>
<td>135.43</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>1528.75</td>
<td>21.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>52642.24</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 18.70%
Table 31 Analysis of variance for Pyriproxyfen 1.0WDG on mortality, inhibition, deformity and emergence of Culex spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>43.05</td>
<td>8.61</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>14769.70</td>
<td>4923.23</td>
<td>397.05</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>51238.49</td>
<td>3415.89</td>
<td>275.49</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>892.75</td>
<td>12.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>66943.99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 14.37%

Table 32 Analysis of variance for Methoprene on mortality, inhibition, deformity and emergence of Aedes spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>18.05</td>
<td>3.61</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>9787.37</td>
<td>3262.45</td>
<td>166.74</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>37217.82</td>
<td>2481.18</td>
<td>126.81</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>1408.75</td>
<td>19.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>48431.99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 17.57%
Table 33 Analysis of variance for Pyriproxyfen 0.5WDG on mortality, inhibition, deformity and emergence of Aedes spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>0.83</td>
<td>0.16</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>10157.83</td>
<td>3385.94</td>
<td>371.62</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>54061.17</td>
<td>3604.07</td>
<td>395.56</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>656.00</td>
<td>9.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>64875.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>12.05%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 34 Analysis of variance for Pyriproxyfen 1.0WDG on mortality, inhibition, deformity and emergence of Aedes spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>3.80</td>
<td>0.76</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>5443.45</td>
<td>1814.48</td>
<td>114.82</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>49924.24</td>
<td>3328.28</td>
<td>210.62</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>1137.75</td>
<td>15.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>56509.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>15.99%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 35 Analysis of variance for field collected IGRs 1.0WDG on mortality, inhibition, deformity and emergence of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>0.85</td>
<td>0.14</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>6167.57</td>
<td>2055.85</td>
<td>148.61</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>42561.43</td>
<td>2364.52</td>
<td>170.92</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>1162.00</td>
<td>13.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>49891.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>14.90%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 36 Analysis of variance for field collected IGRs 1.0WDG on mortality, inhibition, deformity and emergence of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (C)</td>
<td>5</td>
<td>0.85</td>
<td>0.14</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Biol.para(BP)</td>
<td>3</td>
<td>9368.43</td>
<td>3122.81</td>
<td>202.404</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x BP</td>
<td>15</td>
<td>43386.57</td>
<td>2410.36</td>
<td>156.227</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>1296.00</td>
<td>15.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>54051.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>15.69%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 37 Analysis of variance for comparative emergence inhibition by different IGRs against *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>2</td>
<td>399.352</td>
<td>199.676</td>
<td>67.3</td>
<td>0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>6</td>
<td>17.795</td>
<td>2.966</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>417.147</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 1.86%

Table 38 Analysis of variance for comparative emergence inhibition by different IGRs against *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>3</td>
<td>359.442</td>
<td>179.721</td>
<td>77.6</td>
<td>0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>13.893</td>
<td>2.316</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>373.335</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 1.73%
Table 39 Analysis of variance for efficacy of Chrysanthemum extract on *Culex* spp. mosquito 3rd instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>65792.00</td>
<td>9398.85</td>
<td>473.89</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>676.00</td>
<td>676.00</td>
<td>34.08</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>64.00</td>
<td>9.14</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>952.00</td>
<td>19.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>67484.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 8.61%

Table 40 Analysis of variance for efficacy of Chrysanthemum extract on *Culex* spp. mosquito 4th instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>59725.75</td>
<td>8532.25</td>
<td>347.07</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>506.25</td>
<td>506.25</td>
<td>20.59</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>19.75</td>
<td>2.82</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1180.00</td>
<td>24.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>61431.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 11.03%
Table 41 Analysis of variance for efficacy of Chrysanthemum extract on *Aedes* spp. mosquito 3rd instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>74035.75</td>
<td>10576.53</td>
<td>421.65</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>506.25</td>
<td>506.25</td>
<td>20.18</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>223.75</td>
<td>31.96</td>
<td>1.27</td>
<td>0.2830</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1204.00</td>
<td>25.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>75969.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 8.17%

Table 42 Analysis of variance for efficacy of Chrysanthemum extract on *Aedes* spp. mosquito 4th instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>72475.75</td>
<td>10353.67</td>
<td>542.55</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>600.25</td>
<td>600.25</td>
<td>31.45</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>149.75</td>
<td>21.39</td>
<td>1.12</td>
<td>0.3658</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>916.00</td>
<td>19.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>74141.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 7.51%
Table 43 Analysis of variance for efficacy of Neem extract on *Culex* spp. mosquito 3\textsuperscript{rd} instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>79888.00</td>
<td>11412.57</td>
<td>744.29</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>529.00</td>
<td>529.00</td>
<td>34.50</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>155.00</td>
<td>22.14</td>
<td>1.44</td>
<td>0.2101</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>736.00</td>
<td>15.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>81308.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 7.09%

Table 44 Analysis of variance for efficacy of Neem extract on *Culex* spp. mosquito 4\textsuperscript{th} instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>68567.00</td>
<td>9795.28</td>
<td>188.97</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>676.00</td>
<td>676.00</td>
<td>13.04</td>
<td>0.0007</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>124.00</td>
<td>17.71</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>2488.00</td>
<td>51.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>71855.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 14.08%
Table 45 Analysis of variance for efficacy of Neem extract on *Aedes* spp. mosquito 3\textsuperscript{rd} instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>72360.00</td>
<td>10337.14</td>
<td>369.18</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>484.00</td>
<td>484.00</td>
<td>17.28</td>
<td>0.0001</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>244.00</td>
<td>34.85</td>
<td>1.24</td>
<td>0.2976</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1344.00</td>
<td>28.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>74432.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 8.82%

Table 46 Analysis of variance for efficacy of Neem extract on *Aedes* spp. mosquito 4\textsuperscript{th} instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>67399.75</td>
<td>9628.53</td>
<td>207.43</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>870.25</td>
<td>870.25</td>
<td>18.74</td>
<td>0.0001</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>183.75</td>
<td>26.25</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>2228.00</td>
<td>46.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>70681.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 11.81%
Table 47 Analysis of variance for efficacy of Parthenium extract on *Culex* spp. mosquito 3\textsuperscript{rd} instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>75879.75</td>
<td>10839.96</td>
<td>593.97</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>756.25</td>
<td>756.25</td>
<td>41.43</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>897.75</td>
<td>128.25</td>
<td>7.02</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>876.00</td>
<td>18.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>78409.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 7.08%

Table 48 Analysis of variance for efficacy of Parthenium extract on *Culex* spp. mosquito 4\textsuperscript{th} instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>76777.75</td>
<td>10968.25</td>
<td>989.61</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>1190.25</td>
<td>1190.25</td>
<td>107.39</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>571.75</td>
<td>81.67</td>
<td>7.36</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>532.00</td>
<td>11.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>79071.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 6.67%
Table 49 Analysis of variance for efficacy of Parthenium extract on *Aedes* spp. mosquito 3rd instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>60703.75</td>
<td>8671.96</td>
<td>536.41</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>156.25</td>
<td>156.25</td>
<td>9.66</td>
<td>0.0032</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>12205.75</td>
<td>1743.67</td>
<td>107.85</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>776.00</td>
<td>16.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>73841.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation $= 6.50\%$

Table 50 Analysis of variance for efficacy of Parthenium extract on *Aedes* spp. mosquito 4th instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>61769.75</td>
<td>8824.25</td>
<td>670.19</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>2.25</td>
<td>2.25</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>13687.75</td>
<td>1955.39</td>
<td>148.51</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>632.00</td>
<td>13.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>76091.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation $= 6.60\%$
Table 51 Analysis of variance for efficacy of Stevia extract on *Culex* spp. mosquito 3\(^{rd}\) instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>45927.00</td>
<td>6561.00</td>
<td>257.29</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>324.00</td>
<td>324.00</td>
<td>12.70</td>
<td>0.0008</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>220.00</td>
<td>31.42</td>
<td>1.23</td>
<td>0.3039</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1224.00</td>
<td>25.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>47695.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 13.60%

Table 52 Analysis of variance for efficacy of Stevia extract on *Culex* spp. mosquito 4\(^{th}\) instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>46811.75</td>
<td>6687.39</td>
<td>287.62</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>420.25</td>
<td>420.25</td>
<td>18.07</td>
<td>0.0001</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>113.75</td>
<td>16.25</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1116.00</td>
<td>23.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>48461.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 13.46%
Table 53 Analysis of variance for efficacy of Stevia extract on *Aedes* spp. mosquito 3\(^{rd}\) instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>51464.00</td>
<td>7352.00</td>
<td>296.05</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>256.00</td>
<td>256.00</td>
<td>10.30</td>
<td>0.0024</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>396.00</td>
<td>56.57</td>
<td>2.27</td>
<td>0.0436</td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1192.00</td>
<td>24.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>53308.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 12.54%

Table 54 Analysis of variance for efficacy of Stevia extract on *Aedes* spp. mosquito 4\(^{th}\) instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>7</td>
<td>46235.75</td>
<td>6605.10</td>
<td>253.23</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>420.25</td>
<td>420.25</td>
<td>16.11</td>
<td>0.0002</td>
</tr>
<tr>
<td>T x D</td>
<td>7</td>
<td>169.75</td>
<td>24.25</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>1252.00</td>
<td>26.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>48077.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 14.26%
Table 55 Analysis of variance for efficacy of Neem oil on *Culex* spp. mosquito 3rd instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>56905.71</td>
<td>9484.28</td>
<td>292.03</td>
<td>0.000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>1282.57</td>
<td>1282.57</td>
<td>39.49</td>
<td>0.000</td>
</tr>
<tr>
<td>T x D</td>
<td>6</td>
<td>1039.42</td>
<td>173.23</td>
<td>5.33</td>
<td>0.0004</td>
</tr>
<tr>
<td>Error</td>
<td>42</td>
<td>1364.00</td>
<td>32.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>60591.71</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 11.89%

Table 56 Analysis of variance for efficacy of Neem oil on *Culex* spp. mosquito 4th instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>53299.42</td>
<td>8883.23</td>
<td>461.75</td>
<td>0.000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>772.57</td>
<td>772.57</td>
<td>40.15</td>
<td>0.000</td>
</tr>
<tr>
<td>T x D</td>
<td>6</td>
<td>355.42</td>
<td>59.23</td>
<td>3.07</td>
<td>0.0137</td>
</tr>
<tr>
<td>Error</td>
<td>42</td>
<td>808.00</td>
<td>19.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>55235.42</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 9.69%
Table 57 Analysis of variance for efficacy of Neem oil on *Aedes* spp. mosquito 3rd instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>59581.71</td>
<td>9930.28</td>
<td>521.34</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>1170.28</td>
<td>1170.28</td>
<td>61.44</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>6</td>
<td>997.71</td>
<td>166.28</td>
<td>8.73</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>42</td>
<td>800.00</td>
<td>19.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>62549.71</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 8.02%

Table 58 Analysis of variance for efficacy of Neem oil on *Aedes* spp. mosquito 4th instar larvae.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>51002.85</td>
<td>8500.47</td>
<td>656.28</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration (D)</td>
<td>1</td>
<td>714.28</td>
<td>714.28</td>
<td>55.14</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x D</td>
<td>6</td>
<td>185.71</td>
<td>30.95</td>
<td>2.39</td>
<td>0.0447</td>
</tr>
<tr>
<td>Error</td>
<td>42</td>
<td>544.00</td>
<td>12.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>52446.85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 7.18%
Table 59 Analysis of variance for efficacy of botanical extracts against *Culex* spp. mosquito 3rd instar larvae (24 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>115625.14</td>
<td>19270.85</td>
<td>703.56</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>9640.00</td>
<td>2410.00</td>
<td>87.98</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>6560.00</td>
<td>273.33</td>
<td>9.97</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2876.00</td>
<td>27.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>134701.14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 12.42%

Table 60 Analysis of variance for efficacy of botanical extracts against *Culex* spp. mosquito 3rd instar larvae (48 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>127587.20</td>
<td>21264.53</td>
<td>1039.46</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>12213.71</td>
<td>3053.42</td>
<td>149.25</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>7175.08</td>
<td>298.96</td>
<td>14.61</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2148.00</td>
<td>20.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>149124.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 9.23%
Table 61 Analysis of variance for efficacy of botanical extracts against *Culex* spp. mosquito 4th instar larvae (24 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>96764.57</td>
<td>16127.42</td>
<td>635.65</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>4502.17</td>
<td>1125.54</td>
<td>44.36</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>3971.42</td>
<td>165.47</td>
<td>6.52</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2664.00</td>
<td>25.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>107902.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>13.95%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 62 Analysis of variance for efficacy of botanical extracts against *Culex* spp. mosquito 4th instar larvae (48 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>110706.28</td>
<td>18451.04</td>
<td>659.86</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>7236.57</td>
<td>1809.14</td>
<td>64.70</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>5315.42</td>
<td>221.47</td>
<td>7.92</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2936.00</td>
<td>27.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>126194.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>12.18%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 63 Analysis of variance for efficacy of botanical extracts against *Aedes* spp. mosquito 3\textsuperscript{rd} instar larvae (24 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>122674.97</td>
<td>20445.82</td>
<td>699.74</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>11842.74</td>
<td>2960.68</td>
<td>101.32</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>4528.45</td>
<td>188.68</td>
<td>6.45</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>3068.00</td>
<td>29.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>142114.17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 11.19%

Table 64 Analysis of variance for efficacy of botanical extracts against *Aedes* spp. mosquito 3\textsuperscript{rd} instar larvae (48 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>113431.77</td>
<td>18905.29</td>
<td>860.07</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>9207.31</td>
<td>2301.82</td>
<td>104.71</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>20879.08</td>
<td>869.96</td>
<td>39.57</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2308.00</td>
<td>21.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>145826.17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 8.79%
Table 65 Analysis of variance for efficacy of botanical extracts against *Aedes* spp. mosquito 4th instar larvae (24 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>110921.37</td>
<td>18486.89</td>
<td>786.51</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>9674.97</td>
<td>2418.74</td>
<td>102.90</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>5366.62</td>
<td>223.61</td>
<td>9.51</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2468.00</td>
<td>23.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>128430.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>11.14%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 66 Analysis of variance for efficacy of botanical extracts against *Aedes* spp. mosquito 4th instar larvae (48 h).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (T)</td>
<td>6</td>
<td>100159.54</td>
<td>16693.25</td>
<td>701.11</td>
<td>0.0000</td>
</tr>
<tr>
<td>Bot.extract(BE)</td>
<td>4</td>
<td>11633.60</td>
<td>2908.40</td>
<td>122.15</td>
<td>0.0000</td>
</tr>
<tr>
<td>T x BE</td>
<td>24</td>
<td>19425.60</td>
<td>809.40</td>
<td>33.99</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>2500.00</td>
<td>23.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139</td>
<td>133718.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>=</td>
<td>9.91%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 67 Analysis of variance for effect of radiation dose on adult emergence of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>5</td>
<td>7714.20</td>
<td>1542.84</td>
<td>63.29</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>438.75</td>
<td>24.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>8152.95</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 7.56%

Table 68 Analysis of variance for effect of radiation dose on adult deformity of *Culex* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>5</td>
<td>1792.87</td>
<td>358.57</td>
<td>120.08</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>53.75</td>
<td>2.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>1846.62</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 17.50%

Table 69 Analysis of variance for effect of radiation dose on adult emergence of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>5</td>
<td>5701.33</td>
<td>1140.26</td>
<td>67.85</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>302.50</td>
<td>16.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>6003.83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation = 5.57%
Table 70 Analysis of variance for effect of radiation dose on adult deformity of *Aedes* spp.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>5</td>
<td>2362.83</td>
<td>472.56</td>
<td>162.02</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>52.50</td>
<td>2.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>2415.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 13.85%</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 71 Analysis of variance for mating competitions of *Aedes* spp. (No.of mating).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>3</td>
<td>78.68</td>
<td>26.22</td>
<td>35.97</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>8.75</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>87.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 15.01%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 72 Analysis of variance for mating competitions of *Aedes* spp. (Fecundity).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>3</td>
<td>17998.50</td>
<td>5999.50</td>
<td>106.10</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>678.50</td>
<td>56.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>18677.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation = 8.33%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 73 Analysis of variance for mating competitions of *Aedes* spp. (Hatching).

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean square</th>
<th>F-value</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>3</td>
<td>31876.75</td>
<td>10625.58</td>
<td>879.35</td>
<td>0.0000</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>145.00</td>
<td>12.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>32021.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of variation =</td>
<td>11.17%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>