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Insect association with *Parthenium hysterophorus* weed at different habitats of Sungai Petani, Kedah

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DECLARATION

I hereby declare that the work embodied in this Report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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Insect association with *Parthenium hysterophorus* weed

at different habitats of Sungai Petani, Kedah

ABSTRACT

Biocontrol of Parthenium weed is a national agenda in Malaysia. A study (field survey) was conducted at Sungai Petani, Kedah to know insect association with the Parthenium weed and to identify the mechanism of damages caused by the insects. The impact of three different habitats such as residential area, riverside and roadside of Sungai Petani on the diversity of insects on Parthenium weed was also studied. Significant difference insect in diversity and population were noted in different habitats. Both the harmful and beneficial insects of Parthenium weed were found to associate with the weed. The leaf-footed bug, *Acanthocephala femorata* was found to lay eggs on the leaf of Parthenium weed, which the larvae might cause damage to the weed. Some leaf-eating grasshopper were also noted on the plant. Among the three habitats, the residential area sheltered more (61%) insects on Parthenium weed than other habitats.

Keywords: Parthenium hysterophorus, biological control agents, Parthenium insects, leaf-footed bugs, leaf-eating grasshopper

Serangga yang berkaitandengan rumput *Parthenium hysterophorus* pada habitat yang berbeza di Sungai Petani, Kedah

ABSTRAK

Kawalan secara biologi untuk rumpai Parthenium adalah agenda nasional di Malaysia. Satu kajian (tinjauan lapangan) telah dijalankan di Sungai Petani, Kedah untuk mengetahui perhubungan kaitan serangga dengan rumpai Parthenium dan mengenalpasti mekanisme kerosakan yang disebabkan oleh serangga. Terdapat tiga habitat yang berbeza seperti kawasan kediaman, tebing sungai dan tepi Sungai Petani yang memberi kesan dan kepelbagaian serangga pada rumpai Parthenium juga dikaji. Kepelbagaian serangga dan populasi kepadatan yang berbeza telah diperhatikan di dalam habitat yang berlainan. Kedua-dua serangga yang berbahaya dan berfaedah rumpai Parthenium didapati berinteraksi dengan rumpai. Serangga berkaki tebal, *Acanthocephala femorata* didapati bertelur di daun rumput Parthenium, yang mungkin menyebabkan kerosakan pada rumput Parthenium. Terdapat juga belalang yang memakan daun. Di antara ketiga habitat tersebut, kawasan perumahan meliputi lebih banyak (61%) serangga di rumput Parthenium daripada habitat lain.

Kata kunci: Parthenium hysterophorus, ejen kawalan biology, serangga Parthenium, serangga berkaki tebal, belalang pemakan daun

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
SPSS	Statistical Package for Social Science
IAS	Invasive Alien Species

LIST OF SYMBOLS

%	Percentage
m	Meter

CHAPTER 1

INTRODUCTION

1.0 Research Background

Parthenium hysterophorus L. also (Rumput Miang Mexico) is an invasive alien species in Malaysia causing problem to human health, animal health, crop production and biodiversity (Invasive Alien Species) (Karim, 2014). It is also a host of many plant pathogens and insect pests of crop plants (Prasad, 2005). The Parthenium weed might went unrecorded entered India before 1910 via contaminated cereal grain until discovered in 1956 (Sohal S.K, 2002). It was first was brought up to India as ornamental plant but failed, invaded India and Australia as contamination of wheat and pasture seeds that imported for the United State of America (Rao, 1956). The growth of the weed enhanced along with the nitrogenous waste of humans and livestock. This is the cause of the extensive population growth of the weed located near to the cities and human settlement. Under favourable condition the weed become dominant and result in exclusion of beneficial plants (Krishnamurthy K, 1975). Flowering can occur at any time of the year but the flowering are doubled during rainy season (Haq M.R, 2011).

Parthenium weed also noted to survive in most of soil types, dominant in alkaline, clay loam soils (Berry, 1984). Parthenium weed traditionally used for the treatment of fever, headache, arthritis, tootaches, insect bites, infertility and problem during labor and menstrual. The Parthenium weed consist of numerous of important bioactive compound. It has multiple pharmacologic properties that able to contribute to anticancer and anti-inflammatory substance (Fazal H, 2011). Parthenium infestation can degrade the natural ecosystem due to the very high invasive capacity and allelopathic properties that cause disruption to various types of natural ecosystem. The sharp decline of the native biodiversity indicates that the threat of Parthenium towards native biodiversity (Chippendale J.F, 1994). The allelopathic effect and the absence of natural enemies such as insects and disease are the main factors that responsible for the spread of the weed in India (Picman J, 1984).

Weed are important plant resources for insects by the host relationship between insects and plants is highly variable, classified through very specialized to generalize feeding behaviour (Capinera, 2005). The earliest insects were not plant feeders before angiosperm become diverse and abundant, resulting to insect biodiversity expansion (Zherikhin, 2002). Insects have evolved a strong association with plants. By the perspective of crop production, insects are noted as a very destructive, especially in crop monocultures (Smith, 2000). Insect preferences for weed are exploited effectively through the introduction of selective herbivores for the biological suppression of adventive weed. The process of reunite a natural predator with its prey is called as biological control or introduction biological control (Myers, 2003). Weed also affect the chemical based host finding where insect are not using their vision to identify an appropriate habitat, instead they use odour to identify a suitable host. However, through continuous study noted that both vision and odour are important (Judd, 1992). Hostlocation behaviour resulting from visual and chemical orientation was modified by the retention time and behaviour of insects (Finch, 2000). Predators insects with piercing-sucking mouthpart are facultative behaviour due to the feeding preferences are on other insects but imbibing plant sap when necessary to sustain their existence. Thus the presence of certain weed enhance the survival of beneficial insects and assist in biological suppression of pests (Southwood, 2000). Insects that are selective in their feeding habits are influenced by allelochemical or known as secondary metabolites. Plants synthesize a verity of allelochemical compound with different chemical structure that affect the selection and suitability of the plats by the insect (Hanson, 1983). In a coevolutionary sense, insects that are attracted to plants's smell or taste may feed on those plants with the particular chemical which was a barrier to feeding (Futuyma, 1983)

In Malaysia, the weed has occupied the places in 10 states including Sabah. The Malaysian government is worried to control their Invasive Alien Species (IAS). Biocontrol using insect is a sustainable and an eco-friendly approach. Therefore, searching for Parthenium plant-eating insects is an important aspect of Parthenium management.

1.1 Problem Statement

Although the Parthenium weed can be controlled by spraying chemical herbicide, it leads to environmental pollution. Using of biocontrol agent is very important to manage weeds sustainably. Among the biocontrol agents, insects play an important role to manage the problem eco-friendly. No information in this aspect of Parthenium management is available in Malaysia.

1.2 Objective

- To screen out and identify the insects that are associated to the Parthenium weed.
- To identify the mechanism of damage by the insects to the Parthenium weed.
- To compare three different habitats in respect of prevalence of the insects species.

1.3 Hypothesis

i) The insects are associated with the Parthenium weed for its harmful effects to the weed

ii) The nature of damage by the insects is leaf eating by the larvae of the insects

iii) Insect prevalence varies on the basis of habitat.

1.4 Scope of the study

This study will lead to development of biocontrol technology for parthenium control. Environmental safety through reducing the use of chemical herbicides is also within the scope of this study.

1.5 Significance of the study.

By using the biocontrol agent in controlling the Parthenium weed, we can sustain our environment and it is a cost-effective method of Parthenium control. Therefore, identifying insect harmful to Parthenium weed is important to develop biocontrol method of the invasive weed.

1.6 Limitation of the study.

The existence of the weed is limited to certain area of Malaysia and we need to collect the specimen from infested area, which is far from Kelantan. As it is a quarantine pest, we need permission from Department of Agriculture, Malaysia to carry the plants from one place to another.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Parthenium

Parthenium hysterophorus is an allergic weed that invaded many countries of America, Asia, Africa and Australia. The Parthenium weed can be effectively controlled with the application of herbicides. The existence and spread of the weed usually found all along the railway road, waste areas, disturbed sites, lawns and fields of crops. Parthenium reportedly giving a negative effect not only to the human, but also to the livestock and agriculture production. The Parthenium weed can be effectively controlled with the application of herbicides. However, the application of herbicides requires a high cost (Mulatu,2009; Karim,2014).

2.2 Effect human health, livestock health and agriculture production

Parthenium hysterophorus is a type of weed that release one or more biochemical that influences the germination of the plants. This phenomenon is known as allelopathic effect which affect the growth, survival and also the reproduction of an organism. In year 2007, a study was done by Mulatu Wakjira, Gezahegn Berecha and Solomon Tulu, and found that *Parthenium hysterophorus* caused breathing problem such as asthma, skin irritation and some of the victims having postules on the hand (Mulatu, 2009). The existence of Parthenium around the livestock farm caused a big problem livestock production. A large consumption of Parthenium weed by the livestock can cause death, thus increasing the loss by the farmer. In Australia, the Parthenium already spread to the grazing area in Queensland, resulting a reduction of beef production by Au$16.5 million annually (Chippendale, 1994). Parthenium weed caught the attention of the government when the weed reduced the richness and the diversity of other plant species (Sridhara, 2005). Other than that, Parthenium weed also functioned as the host of the plant pathogens and insect pest of economic crops (Prasad, 2005).

2.3 Biological control of Parthenium

O'Donnell (2005) stated that one of the optios of using biological control is using competitive plants to displace Parthenium. He also noted that the Parthenium infestation and the soil seed bank does not reduce if application of fire method was introduced. The smoke treatment from the fire was unable to reduce the infestation of the Pathenium weed germination (Vogler, 2002) . In pasture range areas, the Parthenium was reduced by maintaining the well growth of pasture due to the competition against the Parthenium weed.

2.4 The insects that threaten the Parthenium weeds

Insects were known to cause harm to the health of a plant. Insects are divided into three categories by the feeding mechanism which is chewing, sucking and boring (Conrad, 1997). All the three methods of feeding cause harm to the plants. According to the types of feeding method, the damage symptoms of the insect can be detected through the characteristic patterns. The adult insect usually lay eggs at the leaves, until the larvae are hatched out and bore into the stem through the terminal or axillary meristem, resulting a hollow, fusiform gall. Some adults also chew the leaves and some bores into the stem causing damage and injuries to the plants (McFadyen and McClay, 1981).

2.5. Environmental effects on insects

Insects are known as easily adapting with the environment and able to offspring. The erosion of natural habitat, intruders by outsider, chemicals and pollution in the ecosystem are abundantly intensifies the variations in the environment. The fertility of insects and population dynamics are greatly affected by abiotic and biotic factors. In retaliation on facing the stress from both factors, the insects may prolong the metamorphic stages, survival and rate of multiplication. The immunization of the insect responses as melanisation, lysozyme level and phenoloxidase inhibit the physiological and biological behaviour of insects against different factors like diets, gases and chemicals (Khaliq, 2014). Insects are greatly affected by natural environmental variation and arthopogenic, causing disturbance and altering the population dynamic, distribution, abundance, intensity and feeding behaviour (Ayres, 2009). The biotic stresses in agro-ecosystem modify life cycle and oviposition sheltering success of insects. The environmental pressure caused immunization of the insect by stimulating the neurohormone in mollusks and crustaceans. Immune suppressive changes have been notified with the change inside the environment (Lovett, 2011). Insect feeding and multiplication is significantly high at extensively grazed pasture. Landscape pattern also affected the diversity, thus influencing the landing of flying insects (Holland, 2014). In perspective of insects, the nutrient system in weed also plays a big role in population dynamics. The nutrient are responsible for increasing the herbivory, engulfing extra food, changing the food material or the host shelter. In previous research done by Uddin (2010), noted that there are significantly higher insect population caused by the absence and reduction in natural enemies in a weed free area (Uddin, 2010). The environment of the habitats and caused the great effect on insect occurrence and their abundance (Valantin-Morison, 2007). Response of crowding for an individual and whole insect population can be positive and negative (Debinski, 2000).

2.6 Native range studies

The research from North America, indicated that there were about 262 phytophagous arthropod species and some of fungal pathogens in native range vegetation (Evans, 1997). Among the 262 of phytophagous, about 144 were found to feed on the Parthenium weed at some stage of the life cycle. A number of insects and two rust fungi were released as host range testing in a few area in Australia (Dhileepan, 2001). Based on his study regarding the biocontrol agent for Parthenium weed, there were about 11 types of insects which cause harm and suppress the growth of the weed. The common insect was *Zygogramma bicolorata* that native in Mexico (McFadyen and McClay, 1981). The second major insect is *Epible strenuana*, a type of moth that native to North America (McFadyen, 1982) . The list continued with *Lisronotus setosipennis* (McFadyen, 1985), *Smicronyx lutulentus* (Anderson, 1980), *Conotrachelus albocinerus* (McFadyen, 2000) and *Platphalonidia mystica* (Griffiths, 1993) that were native to Argentina and Brazil. Some of the studies found that *the pathogens, Stubaera concinna, Bucculatrix parthenica, Puccina abrupta* (winter rust) and *Puccina melampodii* (summer rust) also noted as potential biocontrol agent for Parthenium.

2.7 Insect as biocontrol agent of Parthenium

There were two promising biological control agent which are the leaf feeding beetle, *Zygogramma bicolorata* and stem galling moth, *Epible strenuana* (Dhileepan, 2003). A total of nine species and two rust fungi was introduced when first biological control Parthenium was developed in Australia (McFadyen, 1992). The main insect that was used in controlling the Parthenium weed is *Epible strenuana* Walker (Lepidoptera:

Totricidae). The distribution of *Epible strenuana* was around North America and some parts of the Caribbean. In 1982, *Epible strenuana* was introduced from Mexico to Australia after the pre-release host specificity test (McFdyen, 1992; McClay, 1987). The *Epible stranuana* were proven suitable and safe to be used as biological control after the host specificity test was conducted in year 2004 (Jayasuriya, 2005). However in India, the introduction on *Epible strenuana* was not approved due to oviposition and larval feeding on *Guizotia abyssinica* (an annual herbs, which is grown for its edible oil and seeds) and *Helianthus annuus*, one of common sunflower in India (Jayanth, 1987). In South Africa, a venture to manifest a culture of *Epible strenuana* in quarantine didn't achieve the target. The manifest of the *Epible strenuana* did not succeed due to low humidity of the environment. However, an initiative of importing the *Epible strenuana* was be considered (Strathie, 2005). *Epible strenuana* have life span around 7 to 11 days. The female was lay eggs up to 1000 once in a lifetime and the larvae was emerge into the leaf before bore into the stem through terminal or axillary meristem. The feeding of the larvae then was create a hollow, fusiform gall (Raman, 1999). The enlargement of the gall at the early stage of life were quite severe where it able to reduce the plant height, main-stem height, flower production, leaf production, shoot and root biomass (Dhileepan, 2001). Written by Dhileepan and McFadyen, the activity of the *Zygogramma bicolorata* on Parthenium weed was first notified in Australia where the outbreaks showing complete defoliation of small patches within area of 2000km in year 1993 at Queensland (Dhileepan, 1997). The adult and larvae of *Zygogramma bicolorata* were observed to feed on preferable younger leaves of the Parthenium weeds (Annadurai, 1989). The adults lay eggs either in groups or individually at any part of the Parthenium weed before the larvae feed on the younger leaves. The fully grown larvae then enter into the soil to pupate which the pupate cycle last up to two weeks (McFadyen and McClay, 1981; Jayanth, 1987).

Referring to the Indian data, the male live longer than females (Bali, 1993). According to the study done in Queensland, *Zygogramma bicolorata* effecting the defoliation of the weed by 85-100%, reducing the weed density with 31-93%, effecting the plant height by 18-65% and the production of the flower also reduced by 75-100% (Dhileepan, 2000). However, two of the 11 biological control agents were failed to be established on the Parthenium. Some of the biological agent also didn't succeed to reach the desired population level, thus limiting and minimizing the impact on the target weed.

2.8 Factors influencing biological control agent

McFadyen (2003), stated that about 20% to 30% of biocontrol agents that were released were failed to show effectiveness in the weed biological control project in Australia. Most of the biocontrol agents were showing some progress however it didn't achieve the desired level of population which were below the economic injury level. A few of the released insects however had harm to other plants, which also considered as damaging the non-target plant. As example the release of *Zygogramma bicolorata* came out as pest because of the damage done to the sunflower crops in India. A few species of trial from a list of biocontrol agents failed to be establish due to the natural enemies and also different climate from the native range area of the insects. For example, *Zygogramma bicolorata* is a native from Mexico and it took about three years before it was successfully able to be established in India, and it took about four years to be established in Australia. The release of the insect also taking much longer times which means that the application of the biocontrol agent can not give a fast response and an immediate drop of the Parthenium population (McFadyen, 2003).

One of the factors that influence the effectiveness and the spread of the biocontrol agent at the marked area is the natural enemies. The natural enemies can be define as another type of insects that attack the biocontrol agent, thus reducing the effectiveness of the wanted result. According to McClay (1981), the biocontrol agent *Epible strenuana* was attacked by the natural enemies, another types of species from parasitoids and reduced the effectiveness (Spaffrod-Jacob, 2003).

Insects are behaving in adjusting to the environment in order to survive and interacts with the environment. The behaviour of insects encompasses with the relationship with members of its own species, the member of others species and the interaction with physical environment. The behaviour of insects and pest can be classified through the movement (how insects moves), the orientation, dispersion and feeding pattern of the insect. The interaction of the insects rely on the defensive mechanism, reproductive availability and social behaviour of the organism itself.

The interactions between the host plants with the biocontrol agents are affected by the abiotic factor such as the temperature, humidity and rainfall. The abiotic factor that different in each country causing it hard for the biocontrol agent to establish. In example the *Zygogramma bicolorata* favour in a condition summer-like and a heavy rainfall region, causing it to have difficulties in adapting to new place designed for the biocontrol establishment. The Parthenium also affecting the factor due to the stage of lifecycle by the weather. The biocontrol agent might have adapt to the Parthenium at a certain area well but due to weather, the oviposition unable to take place, causing the reproduction phase to limit until a certain lifecycle of the biocontrol agent (Dhileepan, 2003).

Price (1991), noted that the insects which is arthropods favour a large, and vigorously growing plants, in compared to small and slow growing plants. The preference by the biocontrol agent is due to ability to maximize the fitness of the biocontrol agent, thus increasing the population level and maximize the reproduction phase. The biocontrol agent also prefer on plant-produce-flower due to ore effective effect that significantly can be seen. Potential biological agent insect *Epiblema strenuana* are showing less efficient and less vigorous growth of reproduction on the annual plants as the annual plant will reducing the population by being limited to the plant vigor (Price, 1991). Some of the insects are classified as significant pest because they are adapting and accepting with a wide variety of foods (polybags). Insects and pest which are generalist feeders are easily adapting with new crop verities and transgenic crops. The insect also easily adapting and developing resistency towards new type of pesticides. According Matthews, stated in his book titled Insect Behaviour, there are more than 500 species of generalist feeders that targeted by the crop protection strategies which are now resistant to a variety of insecticides (Matthews, 2010). The diversity of the genetic and the effectiveness of the biological control are the reasons of the fitness and establishment of the biological control agents (Wardil, 2004).

CHAPTER 3

MATERIAL AND METHOD

3.1 Materials

The following equipment were needed in order to identify the insects found at the area infected with *Parthenium hysterophorus*;

1. Net for capture the insects.
2. Knife or scissors to cut the area that have symptom affected by the insects.
3. Cool box to gather all the insects or parts of plant that have symptom affected by the insect.
4. Camera to capture the existence of insects either in adult or larva phase.
5. Stereo microscope to identify the insects.
6. Killing jar to kill captured insects.

3.1.2 Chemical reagents.

The chemical reagent needed in this experiment is Ethyl acetate provided by the laboratory to kill the insects captured in the killing jar.

3.2 Methodology

3.2.1 Experimental Layout and site description.

The study was carried out at three different habitats of Parthenium infestation in Kedah. The site observation were done first to know the population of the Parthenium weed weed before the site was selected and was divided into 5 different spots of replication in each habitat (Figure 3.1). For the experimental design, completely randomized design wAS used with W shaped pattern of sampling technique. The size of the plot was more or less same in different habitats.

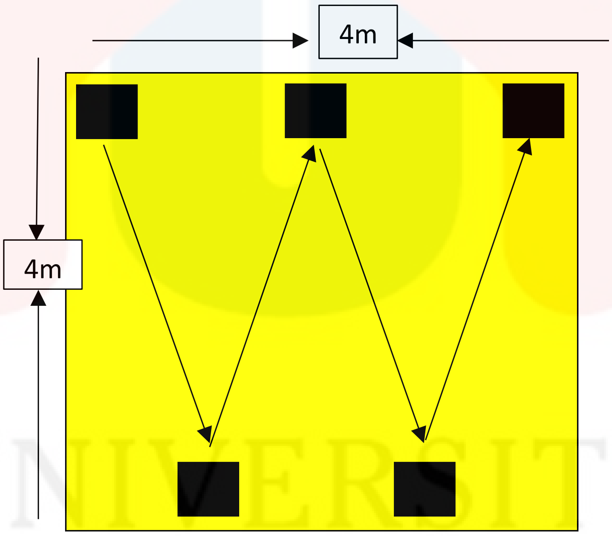


Figure 3.1: Size and pattern of each plot

3.2.2 Collection, identification and analysis of insect collected

The samples were collected at three different locations in Kedah (Appendix A). Four meter square pattern were planned. The collection of insects was done by using net before placed into the cool box. The experiment pattern used for this study was 'W' pattern. The insects collected was brought back to the UMK laboratory for identification and analyse. By using knife or scissor, the parts of the plants that showed some damages symptoms were be cut and placed in the cool box. All of the procedure and sample collection captured by using camera. The insects collected were killed by using Ethyl acetate and dried in oven with temperature of 45 – 55 ˚C for preservation. The dried sample were pinned for identification process by using stereo microscope (Appendix B). The sample identification were referred to the book of Study of Insects 7th Edition by Charles Triplehorn and Norman Johnson (2005). The parts of the plants that showed symptom were identified. The number of collected insects were grouped under different categories and under different orders (Appendix D).

3.2.3 Determination of insect diversity

The samples identified were categorized by the population and the diversity of fauna at different habitat. The insect diversity was calculated by using Simpson's Index (D).

$$\textbf{Simpson's Index (D)} = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

where n_i = the total number of organisms of each individual species

N = the total number of organisms of all species

The value D calculated are range from 0 to 1. 0 value representing the infinite diversity. Value of 1 representing no diversity. The lower is the value and the higher is the diversity. When the value of D $\geq$ 0.5 shows low level of diversity of the sampled habitat. When the value D $\leq$ 0.5 show the high level of diversity of the habitat. The species richness is biased towards scarce species. The species evenness is biased towards dominant species (Goudarzian, 2007).

3.3 Experimental design and statistical analysis

The experimental design used was Completely Randomized Design. To analyse the data of the experiment, One-way ANOVA was used because it is only one factor experiment by using SPSS Programme.

CHAPTER 4

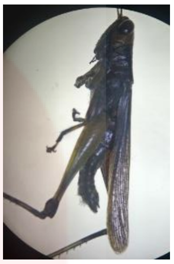
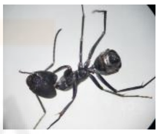
RESULT AND DISCUSSION

4.1 Insects associated with the Parthenium weed

Different kinds of insects were found that associate with the Parthenium weed under three different habitats (Appendix B). Nine kinds of insect under 8 families are noted in the research sites at Kedah (Appendix D). Among the eight categories of insect, three were sap-sucking bugs e.g *Zelus longipes, Podisus maculiventris* and *Acanthocephala femorata*. There were three leaf-eating insects, e.g *Atractomorpha crenulata, Tettigonia viridissima* and *Ruspolia nitidula*. Two species, *Camponotus gigas* and *Vespa affinis* were found to help in pollination of Parthenium flowers (Table 4.1.1).

Table 4.1.1: Morphology and Identification of insect collected at Parthenium infestation area.

Profile	Description	Picture
Order: Coleoptera Family: Coccinellidae Scientific name: *Harmonia axyridis*	Yellow in colour with dotted black. Found flying at the area of Parthenium weed. Captured at the leaf of the Parthenium weed.	
Order: Hemiptera Family: Reduviidae Scientific name: *Zelus longipes*	Orange with black pattern on the body. Hiding under the leaves of Parthenium weed.	
Order: Hemiptera Family: Coreidae Scientific name: *Acanthocephala femorata*	Known as one of the true bugs. Dull reddish and dull brown in colour. Found in large number quantity. Lay eggs at the leaf of Parthenium.	

Order: Hemiptera Family: Pentatomidae Scientific name: *Podisus maculiventris*	Thin legs, brown in colour. Found flying at the Parthenium infestation area.	
Order: Orthoptera Family: Acrididae Scientific name: *Tettigonia riridissima*	Green in colour. Found jumping from a place to another at Parthenium weed.	
Order: Orthoptera Family: Acrididae Scientific name: *Ruspolia nitidula*	Dark brown in colour. Found jumping from a place to another at Parthenium weed.	
Order: Orthoptera Family: Pyrgomorphidae Scientific name: *Atractomorpha crenulata*	Long and green body. Found at the leaf of Parthenium weed.	
Order: Hymenoptera Family: Formicidae Scientific name: *Camponotus gigas*	Black in colour. Found at the floor, leaves and stem of Parthenium weed.	
Order: Hymenoptera Family: Vespidae Scientific name: *Vespa affinis*	Black in colour with yellow band. Flying over the Parthenium weed area.	

All the insects might be related directly or indirectly to the harmful effect o Parthenium weed. However, I could not find any insect listed in this thesis to eat or suck to the Parthenium leaves or stem at the time of the investigation.

The most dominant insect's family that found on the Parthenium weed was Coreidae. Leaf-footed bugs is well known in the family of Coreidae as serious pest insect that typically damaging cultivated crops such as tomato, peaches, citrus, sunflower (Donald, 2003).

The second highest order of insects captured were Hymenoptera. Hymenoptera are one of important plant pollinators and a regular flower visitor and nectar is the source of energy (Gadagkar, 1991). In tropical community and temperate area, the wasp from order Hymenoptera (family Vespidae) are commonly flies to collect water, plant fibre and carbohydrate as source of food. This wasp hunts the arthropods prey and scavenge animal protein (Edwards, 1980). Ants (Hymenoptera: Formicidae) are an important component of the ecosystem, constituting a large part of animal biomass (Nayana, 2016).

The order of Orthoptera are consist of two different families collected which are Pyrgomorphidae and Acrididae. One species of the Pyrgomorphidae is *Pyrgomorpha vignaudii* that are known as pest at the area of Tropical environment (Paraiso, 2012). The insects from Pyrgomorphidae feeds on wide range of crops such as coffee and banana, also certain weed plants (Chapman, 1986). Most of the species of grasshopper are known as a well adapter to the habitat which are altered by western agricultural practices (Pdaft, 1994). The grasshopper can result in widespread and severe damages to grasslands, forage, cereal, vegetable and orchard crops (Lockwood, 2002).

The least number of insects collected are from the family of Coccinellidae of the Order Coleoptera. In several locations of South America, *Eriopis connexa* were reared for biological control programmes, and have a good adaptability to various preys that very in polyphagous feeding habit. Thus, it is the potential insect by controlling the pest of crops such as corn and sorghum (Silva, 2013).

4.2. Insect sheltering on the Parthenium plant

Two species of insect were found to shelter on the Parthenium weed plant. One insect, *Acantocephala femorata* was noted to lay many eggs on the leaf of Parthenium plant (Figure 4.2.1). Another larva was noted crawling on the stem of the Parthenium (Figure 4.2.2). The eggs might be hatched out later and the larva may depend on the tender leaves of the host plant. The larva which was crawling on the stem also might be damaging to the Parthenium weed. However, during the field survey, I did not mark it to eat any plant part of the Parthenium weed.

Figure 4.2.1 Presence of brown coloured egg mass on the leaves of Parthenium.

4.2.2 The presence of caterpillar at the Parthenium plant.

The eggs were from the species of *Acanthocephala femorata* (Hemiptea: Coreidae). *Leptoglossus* species feed on foliar tissue and fruit by piercing the selected plant tissue with their proboscis and sucking the juices. The saliva of leaf-footed bugs contains a toxic secretion, which further injures plant tissue (Thomas, 2010).

4.3 Effect of habitats on the insect diversity on Parthenium weed

Different kinds of insects were collected from three different habitats (Table 4.3.1). From three different habitat, there are 100 insect sample were collected, which were categorized into two groups, beneficial insect group and harmful insect group in association with Parthenium weed. Beneficial insect (*Vespa affinis* and *Camponotus gigas*) help to pollinate the Parthenium flowers which is with negative impacts on Parthenium management. There was significant difference between insect population recorded from Parthenium weed in three different habitats (Appendix C).

Table 4.3.1: Insects Collected from Different habitats of *Parthenium hysterophorus* Population at Sungai Petani, Kedah.

Habitat	Total	Mean	Percentage
Habitat 1 (roadside)	25	6	25%
Habitat 2 (residential area)	62	16	61%
Habitat 3 (riverside)	14	4	14%
Total	101		100%

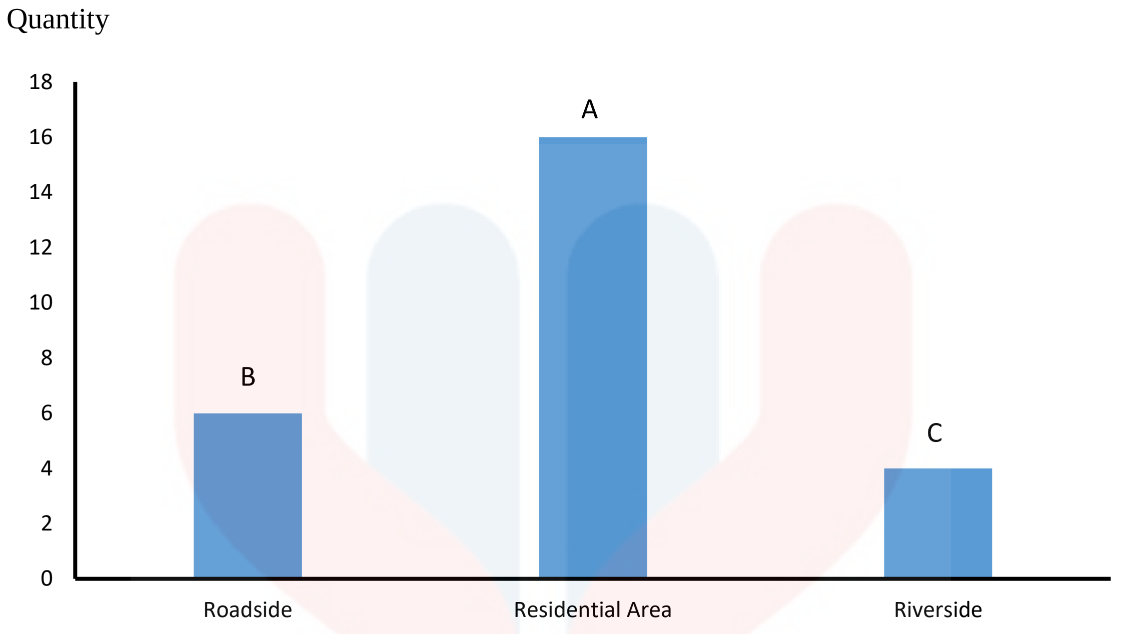


Figure 4.3.1 Insect availability on Parthenium at different habitats in Sungai Petani, Kedah.

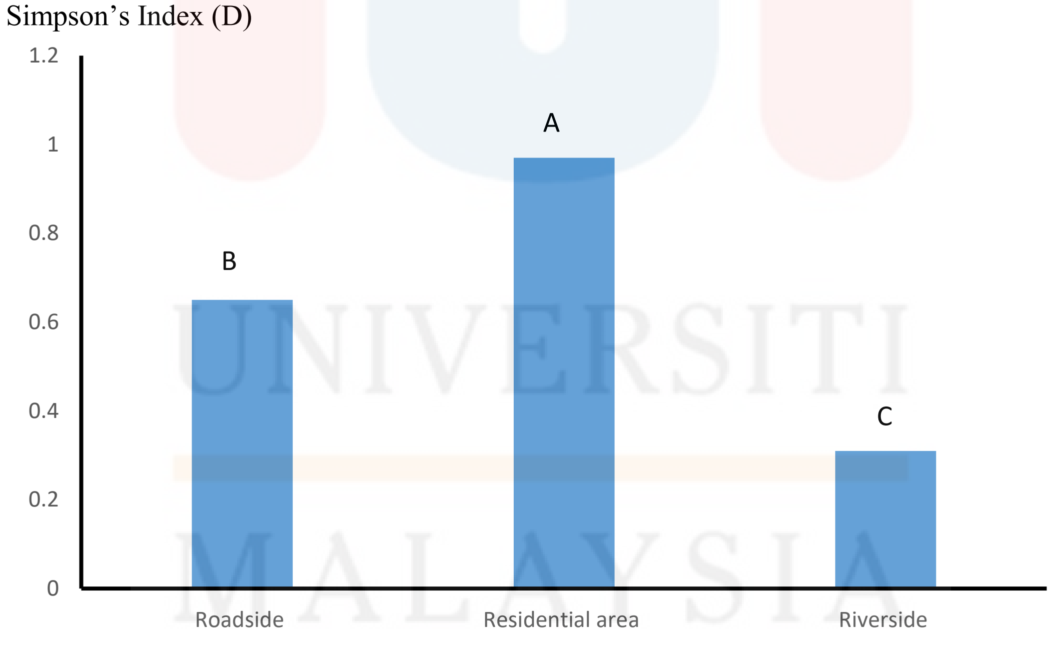


Figure 4.3.2: Simpson's Index indicating insect diversity on Parthenium weed at three different habitats in Sungai Petani, Kedah

Among all three habitats, the residential area was noted to have the highest population (61%) of the insects compared to other habitats (Figure 4.3.1). The riverside area sheltered less number of insects (14%).

While the insect diversity was estimated using Simpson's Index, it was noticed that again the highest diversity was found in residential area (D=0.97) and the lowest diversity was in riverside (Figure4.3.2)

According to research by Mdhumitha, there are four kinds of insects found at the residential area which are beetles (Coleoptera), Flies (Diptera), bugs (Hemiptera) and ants (Hymenoptera) (Madhumitha, 2013). The urban environments commonly give shelter to large population of herbivores that considered as pest. The success of insect association might be due to several factors such as low natural enemy, phenological shifts, no presence of toxic host plants and urban warming (Bleakly, 2018). Theoretically the population of insect would be higher at the area of roadside and riverside due to no application of pesticides and no disturbance from human. However, according to research done by Pilar et al., (1997) roadside negatively effected the abundance, evenness and diversity of insects due to two major factors. The first factors are caused by the high mortality of some groups when crossing the roads and more impact of higher traffic volumes. According to previous research done by Findlay and Houlahan (1997), the road construction do involves fragmentation and alteration of the natural habitat (Findlay, 1997). The insect population may decrease because of the alternation of the original habitat during the road construction.

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 Conclusion

This study focuses on the insect association with the Parthenium weed at Kedah, Malaysia. Among eight different kinds of insects collected most are suspected to cause damages to the Parthenium either by eating the leave or sucking the cell saps of the Parthenium plant tissue. The residential area, in comparison to roadside and riverside, is the best habitat for sheltering the Parthenium insect-pest. In that habitat, diversed insects are found with Parthenium plant. The insect *Acanthocephala femorata* might be good candidate for biocontrol of Parthenium due to the presence and sheltering at Parthenium weed, which need more details study.

5.2 Suggestion for further study.

More study covering different habitats thorough survey throughout the country is needed. During survey special attention should be give to isolate and identify if the *Zygograma bicolorata* can be found in the country. If that insects is available, we can rear and multiple the species for successful biocontrol of Parthenium weed in Malaysia.

References

Anderson, D. N. (1980). A revision of the species *Smicronyx Schoenherr* (Coleoptera: Curculionidae) occuring in America north of Mexico. Proceeding of the United State Natural Museum, (pp. 1-185). Mexico.

Annadurai, D. N. (1989). Reproductive potential in terms of quantitative food utilisation of *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) on *Parthenium hysterophorus* (Asteraceae). In Proceeding of the VII International Symposium on the Biological Control of Weeds helds in Rome (pp. 385-394). Melbourne, Australia: E. S. Delfosse.

Ayres, S. D. (2009). The role of anorexia in resistance and tolerance to infections in Drosophila. Phillosophy of Biology, 1000-1005.

Bali (1993). Biological studies on *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelida), A biocontrol agent of *Parthenium hysterophorus* L. (Asreraceae). Journal Of Biological Control (pp. 101-113).

Berry. (1984). Feverfew faces the future. Pharmaceutical Journal., 611-614.

Bleakly, E. N. (2018). Influence of Urbanisation And Plant On The Diversity And Abundance of Aphids and Their Ladybird And Hoverfly Predators in Domestic Gardens. International Journal of Zoology and Applied Bioscience. (pp.12-17).

Capinera, J. L. (2005). Relationships between insect pests and weeds: an evolutionary perspective. Weed Science, Vol. 53, No. 6, 892-901.

Chapman, W. P. (1986). Bioeconomic of the variegated grashhopper *Zonocerus variengetus* in west and central Africa. Ann. Rev. Entomol, 479-505.

Chippendale J.F, P. F. (1994). The cost of Parthenium weeds to the Queensland cattle industry. Plant Protection Quarterly., 73-76.

Chippendale, J. F. (1994). The cost of Parthenium weed to the Queensland cattle industry. Plant Protection Quaterly, 73-76.

Conrad (1997). Insect Mouthpart: Ascertaining the paleobiology of insect feeding strategy. Washington: Annual Review of Ecology and Systematic. (pp. 56-69).

Debinski, R. D. (2000). A survey and overview of habitat fragmentation experiments. Conservation Biology, 342-355.

Dhileepan. (1997). Biological control of Parthenium in Australia progress and prospects. In First International Conference on Parthenium Managaement, Vol I, ed. M. Mahadevappa and V. C. Patil. (pp. 40-44). Dharwad, India: University of Agricultural Sciences.

Dhileepan. (2001). Effectiveness of introduced biocontrol insects on the weed Parthenium hysterophorus (Asteraceae) in Australia. Australia: Bulletin of Entamological Research . (pp. 67-77)

Dhileepan. (2003). Seasonal variation in the effectiveness of leaf-feeeding *Zygogramma bicolorata* and stem-galling moth *Epible strenuana* as biocontrol agents on the weed Parthenium hysterophorus. Bulletin of Entomological Research.

Donald, H. S. (2003). Pest Status of Leaf Footed Bugs (Heteroptera: Coreidae) on Citrus in Louisiana. Proceeding of. Florida State Horticulture. Soc, 240-241.

Edwards. (1980). Social Wasps: Their Biology and Control. Sussex, UK: Rentokil, 398.

Evans, H. C. (1997). The potential of neotropical fungal pathogens as classical biological control agents for management of *Parthenium hysterophorus* L. In First International Conference on Parthenium Management, ed M. Mahadeveppa and V. C. Patil. (pp. 55-62). Dharwad, India: University of Agricultural Science.

Fazal H, A. N. (2011). Antibacterial potential in *Parthenium hysterophorus*, *Stevia rebaudiana* and *Ginkgo biloba*. Journal of Botanical , 1307-1313.

Finch, S. a. (2000). Hist plant selection by insects- a theory based on 'appropriate/ inappropriate landings' by insects of cruciferous plants. . Entomol. Exp. Appl. , 91-102.

Findlay, H. J. (1997). Anthropogenic correlates of species richness in southeastern Ontario wet-lands. Conservation Biology, 1000-1009.

Franceline Doh, K. Y. (2016). Biological Cycle of Bugs *Pseudotheraptus devastans* Distant (Heteroptera: Coreidae), the Coconut Pest in Cote d'Ivoire. Advances in Entomology, Scientific Reasearch Publishing, 19-24.

Futuyma, D. J. (1983). Selective factors in the evolution of host choice by phytophagous insects. Herbivorous insects: Host seeking behaviour and mechanism. , 227-244.

Gadagkar, R. (1991). Belanogaster, Myschocyttarus, Parapolybia, and independent-founding Ropalidia. The Social Biology of Wasp (pp. 149-190). New York: Cornell University.

Goudarzian, E. (2007). The efficiency of indices of richness, evenness and biodiversity in the investigation of species diversity changes (case study: migratory water birds of Parishan international wetland, Fars province, Iran). Biodiversity International Journal Volume 1 Issue 2, 41-45.

Griffiths, M. W. (1993). Biology and Host specificity of *Platphalonidia mystica* (Lep: Cochilidae) introduced into Queensland to biologically control *Parthenium hysterophorus* (Asteracheae). Queensland, Australia: Entomophaga.

Hanson, F. E. (1983). The behavioral and neurophysiological basis of food plant selection by lepidopteroua larvae. . Herbivorous insects: Host-seeking behavior and mechanisms. , 3-23.

Haq M.R, A. S. (2011). In vitro *Parhenium hysterophorus* extracts against human cancerous cell lines. Journal of Chemical and cytotoxicity of Pharmaceutical Research., 601-608.

Holland, S. (2014). Utilisation of agri-environment scheme habitats to enhance invertebrate ecosystem service providers. Agriculture, Ecosystem and Environment, 103-109.

Jayanth. (1987). Investigation on the host specificity of *Epible strenuana* Walker (Lepidoptera: Totricidae), introduce for biological control trials against *Parthenium hysterophorus.* Journal of Biological Control.

Jayasuriya, A. H. (2005). Parthenium weed- status and management in Sri Lanka . In Second International Conference on Parthenium Mnagament, ed. T. V. R,achandran Prasad, H. V. Nanjappa, R. Devendra eet. al (pp. 36-43). Bangalore, India: University of Agricultural Sciences.

John H. Klotz, J. R. (March 1995). Survey of The Urban Pest Ants (Hemiptera:Formicidae) of Peninsular Florida. Florida Entomologist Online Vol 78, No 1, 109-119.

Judd, G. (1992). Aggregated oviposition in *Delia antiqua*: a case for mediation by semiochemicals. Journal of Chemical Ecology, 621-635.

Karim, S. M. R. (2014). Malaysia Invaded: Weed it out Before It Is Too Late. Kedah, Malaysia: Tropical & Sub-Tropical Weed Research Unit, The University of Queensland, Australia. .

Khaliq, M. J. (2014). Environmental effects on insects and their population dynamics. Journal of Entomology and Zoology Studies. 1-7.

Krishnamurthy K, R. P. (1975). Agriculture and health hazards of Parthenium. Current Research, 169-171.

Laan, M. (2006). Allelopathic interference potential of the alien invader plant *Parthenium hysterophorus.* South Africa: University of Pretoria.

Lockwood, A. J. (2002). Whne less is more: Optimization of reduced agent-area treatment for management of rangeland grasshopper. Crop Prot, 551-562.

Lovett, A. A. (2011). Some like it hot: the effects of climate change on reproduction, immune function and disease resistance in the cricket Gryllus texensis. The Journal of Experimental Biology, 1997-2004.

Madhumitha, L. S. (2013). Patterns of Insect Abundance and Distribution in Urban Domestic Gardens in Bangalore, India. Open Access Diversity, 1-12.

Matthews, J. M. (2010). Chapter 4; Forging and Feeding. In J. M. R. W. Matthews, Insect Behaviour 2nd Edition (pp. 131-137). New York: Springer.

McFadyen and McClay, A. R. (1981). Two new insects for the biological control of Parthenium weed in Queensland. In Proceeding of the Sixth Australian Weeds Conference ed. B. J. Wilson and J. D. Swarbrick (pp. 145-149). Brisbane, Australia: Australia: Weed Science Society of Queensland.

McFadyen. (1982). Host specificity of Parthenium stem galling moth *Epible strenuana* Walker from Mexico, a potential biocontrol agent against *Parthenium hysterophorus* in Queensland. Sherwood, Brisbane: Internal Report, Alan Fletcher Research Station.

McFadyen. (1985). The biological control programme against *Parthenium hysterophorus* in Queensland. In Proceeding of the VI International Symposium on the Biological Control of Weeds, ed. E. S. Delfosse (pp. 789-796). Vancouver, Canada: Canada: Agriculture Canada.

McFadyen. (2000). Biology and host specificity of the stem galling weevil *Conotrachelus albocinereus* Fielder, A potential agent for Parthenium weed in Queensland, Australia. Queensland, Australia: Biocontrol Science and Technology. Pp. 12-15

McFadyen. (2003). Does ecology hep in the selection of biocontrol agents? In Improving the Selection, Testing and Evaluation of Weed Biological Control Agents, ad. H. Spaffod-Jacob and D. T. Briese (pp. 5-9). Adelaide, Australia: CRC for Australian Weed Mangement.

Mitchel, R. W. (2006). Relationship between avian richness and landscape structure at multiple scale using multiple landscapes. Forest Ecology and Management. 155-169.

Mulatu, W. G. (2009). Allelopathic effects of an invasive alien weed. Ethiopia: Academic Journal.

Myers, J. H. (2003). Ecology and control of introduced plants. . Cambridge University Press. (pp. 94-158). Cambridge, Great Britain: Cambridge University Press.

Nayana, P. P. (2016). Comparison of Ant (Hymenoptera: Formicidae). Diversity in Different Habitats of Machad Region of Thrissur. Bull Env Pharmacol Life Sci, 28-33.

O'Donnell, C. A. (2005). Management of Parthenium weed through competitive displacement with beneficial plants. Washington: Weed Biology and Management.

Panizzi, A. R. (December 2004). A possible territorial or recognition behavior of *Leptoglossus zonatus* (Dallas) (Heteroptera: Coreidae). Scientific Communication, 577-579.

Paraiso, A. K. (2012). The Acridoidea of Benin (Orthoptera): an anecdote checklist. International Journal of Science and Advamced Technology, 22-52.

Patrick Marc, A. C. (1999). Spider (Araneae) useful for pest limitation and bioindication. Agriculture Ecosystem and Environment, 229-273.

Picman J, P. A. (1984). Auto toxicity in *Parthenium hysterophorus* L. and its possible role in control of germination. Biochem. Syst. Ecol. 12, 287-292.

Pilar Tamayo, F. P. (March 2014). Effects of roads on insects. Biodiversity and Conservation, 659-682.

Prasad, R. D. (2005). Role of Parthenium in perpetuation and spread of plant pathogens. In Second International Conference on Parthenium Management (pp. 65-72). Bangalore, India: University of Agricultural Science.

Price, P. W. (1991). Plant vigor hypothesis and herbivore attack. . Washington: Oikos.

Raman, A. A. (1999). Qualitative evaluation of damage by *Epiblema strenuana* (Lepidoptera: Totricidae) to the weed *Parthenium hysterophorus* (Asteraceae). America: Annals of Entomological Society of America.

Rao. (1956). *Parthenium hysterophorus* Linn. A new record for Indian J. Bombay Nat. Hist. Soc., 218-220.

Sao (2016). Preliminary studies on the spider fauna in selected agro-ecosystem of Kozhinjampara Panchayat, Palakkad District, Kerala. International Journal of Recent Scientific Research Vol 7, Issue 10, 13740-13743.

Silva, R. C. (2013). Biological aspects of *Eriopis connexa* (Germar) (Coleoptera: Coccinellidae) fed on different insect pests of maize (Zea mays L.) and sorghum (Sorghum bicolor L.). Braz. J. Biol., 2013, vol. 73, no. 2,, 419-424.

Smith, H. A. (2000). Intercropping and pest management: a review of major concept. Entomology, 39-50.

Sohal S.K, R. P. (2002). Evaluation of the pesticidal potential of the congress grass, *Parthenium hysterophorus* Linn. on the mustard aphid, *Lipaphis erysimi* (Kalt.). Journal of Environmental Biology / Academy of Environmental Biology, India, 15-18.

Southwood, T. (2000). Intercropping and pest management: a review of major concepts. Journal of Entomology, 154-161.

Spaffrod-Jacob, M. A. (2003). Insects for the biological control of weeds: predicting parasitism level in new country. In Proceeding of the XI International Symposium of Biological Control of Weed, ed. J. M. Cullen, D. T. Briese, D. J. Kritocos, et al. (pp. 135-140). Canberra, Australia

Sridhara, S. B. (2005). Temporal Variation in relative dominance of *Parthenium hysterophorus* and its effect on native biodiversity. In Proceeding of the Second International Conference on Parthenium Managment (pp. 240-242). Bangalore, India: University of Agricultural Science.

Strathie, L. W. (2005). *Parthenium hysterophorus* (Asteraceae) in southern Africa, and initiation of biologocal control againts it in South Africa. In Proceeding of the Second International Conference on Parthenium Management, ed. T. V. Ramachandra Prasad, H. V. Nanjappa, R. Devendra, et al. (pp. 123-133). Bangalore, India: University of Agricultural Sciences.

Thomas, J. J. (2010). Leaf-Footed Bugs. Virginia Corporative Extension., 3012-1522.

Uddin (2010). Effect of weed removal on insect populations and yield of cowpea (*Vigna unguiculata*). Autralian Journal of Agricultural Engineering, 194-199.

Valantin-Morison, M. J. (2007). Effect of crop management and surrounding field environment on insect incidence in organic winter oilseed rape (*Brassica napus* L.). Crop Protection, 1108-1120.

Via, S. (1986). Genetic covariance between oviposition preference and larval performance in an insect herbivore. Department of Zoology, Duke University, Durham., 778-785.

Vogler, W. N. (2002). Use of fire to control Parthenium weed. Australia: A report for the Rural Industries Research and Development Corporation.

Wardil, T. J. (2004). The importance of species identity in the biocontrol process. In Proceeding of the Fourteenth Australian Weed Conference, ed. B. M. Sindel and S. B. Johnson (pp. 364-367). Sydney, Australia: Weed Society of New South Wales. .

Zherikhin, V. V. (2002). Ecological history of the terrestrial insects. History of insects, 331-388.

Appendix A – Scenario of Parthenium infestation at Sungai Petani, Kedah.

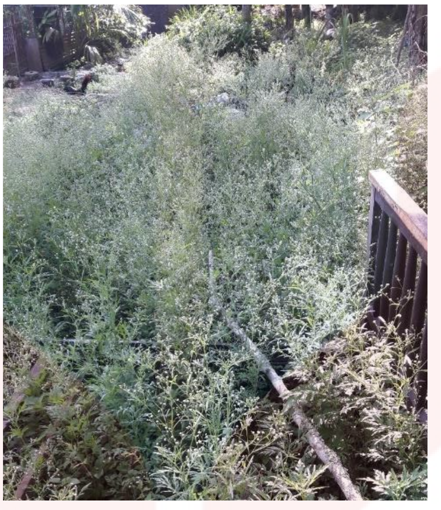


Figure A.1: Parthenium infestation at Roadside.

Figure A.2: Parthenium infestation at Riverside

Figure A.3: Parthenium infestation at Residential area.

Appendix B- The insects collected from the Parthenium plants at survey site.

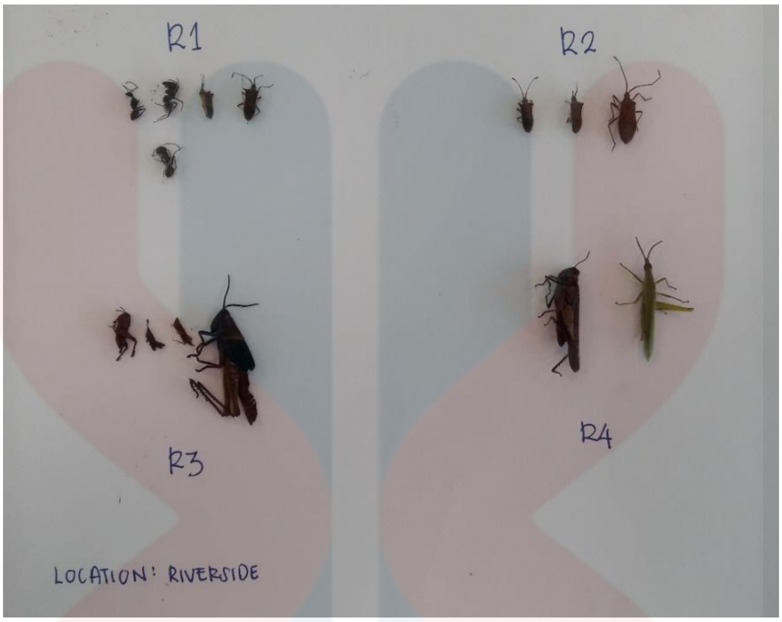


Figure B.4: Insect collected at Riverside.

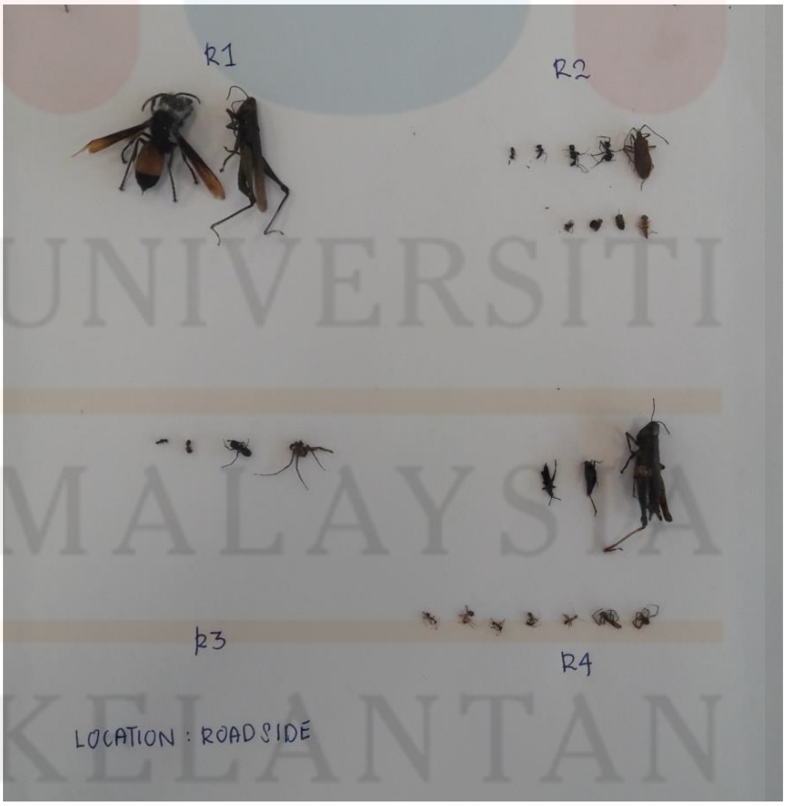


Figure B.5: Insect collected at Roadside.

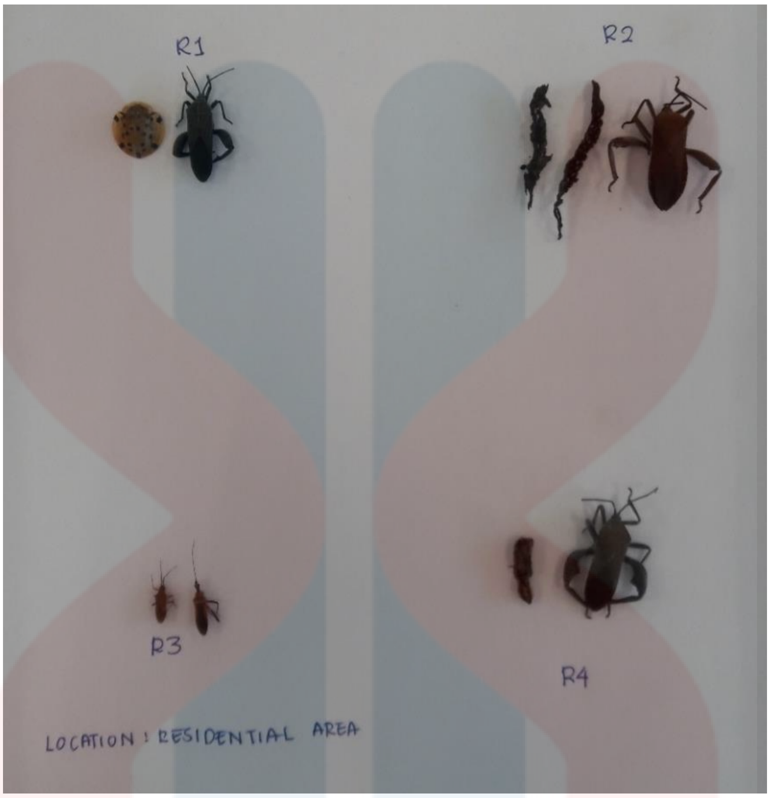


Figure B.6: Insect collected at Residential area.

Appendix C - ANOVA table and Tukey Test of the dataon insect diversity at three habitats.

Oneway

[DataSet0]

Descriptives

Order

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Roadside	25	3.9200	.70238	.14048	3.6301	4.2099	2.00	5.00
Residential Area	61	1.9836	.12804	.01639	1.9508	2.0164	1.00	2.00
Riverside	14	2.8571	.77033	.20588	2.4124	3.3019	2.00	4.00
Total	100	2.5900	.94383	.09438	2.4027	2.7773	1.00	5.00

Test of Homogeneity of Variances

Order

Levene Statistic	df1	df2	Sig.
26.619	2	97	.000

ANOVA

Order

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	67.652	2	33.826	159.760	.000
Within Groups	20.538	97	.212		
Total	88.190	99			

Robust Tests of Equality of Means

Order

	Statistic[a]	df1	df2	Sig.
Welch	99.259	2	22.882	.000
Brown-Forsythe	76.295	2	30.549	.000

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Order

Tukey HSD

(I) Habitats	(J) Habitats	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Roadside	Residential Area	1.93639*	.10927	.000	1.6763	2.1965
	Riverside	1.06286*	.15360	.000	.6973	1.4285
Residential Area	Roadside	-1.93639*	.10927	.000	-2.1965	-1.6763
	Riverside	-.87354*	.13636	.000	-1.1981	-.5490
Riverside	Roadside	-1.06286*	.15360	.000	-1.4285	-.6973
	Residential Area	.87354*	.13636	.000	.5490	1.1981

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Order

	Habitats	N	Subset for alpha = 0.05		
			1	2	3
Tukey HSD[a,b]	Residential Area	61	1.9836		
	Riverside	14		2.8571	
	Roadside	25			3.9200
	Sig.		1.000	1.000	1.000
Duncan[a,b]	Residential Area	61	1.9836		
	Riverside	14		2.8571	
	Roadside	25			3.9200
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 23.470.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Appendix D – Categorization of collected insects under different orders and families.

Table D.1: diversity of insect in three habitats altogether

Order	Number of individuals of each order in each habitat			Percentage Number of individuals of each order (%)
	Roadside	Residential area	Riverside	
Coleoptera		1		1.0
Hemiptera	1	60	5	66.3
Ortophtera	4	-	6	10.0
Hymenoptera	16	-	3	18.7
Araneae	4	-	-	4.0
Total number of insects (N)	25	61	14	

Table D.2: Numbers of individual order and family at Roadside area.

Order	Family	Quantity	Percentage (%)
Coleoptera	-	-	-
Hemiptera	Pentatomidae	1	4
Ortophtera	Acrididae	4	16
Hymenoptera	Vespidae	1	4
	Formicidae	17	68
Araneae	Spider	2	8
Total		25	100

Table D.3: Numbers of individual order and family at Residential area.

Order	Family	Quantity	Percentage (%)
Coleoptera	Coccinellidae	1	1.6
Hemiptera	Coreidae	59	95
	Pentatomidae	1	1.6
	Reduviidae	1	1.6
Ortophtera	-	-	-
Hymenoptera	-	-	-
Araneae	-	-	-
Total		62	100

Table D.4: Numbers of individual order and family at Riverside.

Order	Family	Quantity	Percentage (%)
Coleoptera	-	-	-
Hemiptera	Pentatomidae	4	21.4
	Coreidae	1	7.1
Ortophtera	Pyrgomorphidae	1	42.9
	Acrididae	5	
Hymenoptera	Formicidae	3	7.1
			14.3
Araneae	-	-	-
Total		14	100