CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Fire Ants, *Solenopsis sp.*

2.1.1 Brief History

About 110 and 130 million years ago, ants evolved from wasp-like ancestors. More than 12,500 out of an estimated total of 22,000 species have been classified. Ants occupy a wide range of ecological niches, and are able to exploit a wide range of food resources either as direct or indirect herbivores, predators, and scavengers. Ants thrive in most ecosystems. Ants have colonised almost every landmass on Earth. The only places lacking indigenous ants are Antarctica and a few remote or inhospitable islands. Most species are omnivores in general, but a few are specialist feeders. Ants can be identified by their distinctive elbowed antennae and a node-like structure that forms a slender waist (Schultz, 2000).

2.1.2 Ant General Taxonomy

General taxonomy of ants is described as below:

Kingdom : *Animalia*

Phylum : *Arthropoda*

Class : *Insecta*

Order : *Hymenoptera*

Suborder : *Apocrita*

Superfamily : *Vespoidea*

Family : *Formicidae*

2.1.3 Taxonomy of Fire Ants, Solenopsis sp.

Taxonomy of the Solenopsis sp. used in this research is:

Kingdom *: Animalia*

Phylum *: Arthropoda*

Class *: Insecta*

Order *: Hymenoptera*

Family *: Formicidae*

Sub family *: Myrmicinae*

Tribe *: Solenopsidini*

Genus *: Solenopsis sp.* (Bolton et al, 2007)

2.1.4 Morphology of Adult Ants

Ants have an exoskeleton, an external covering that provides a protective casing around the body and a point of attachment for muscles, in contrast to the internal skeletons of humans and other vertebrates. Ants do not have lungs; oxygen and other gases such as carbon dioxide pass through their exoskeleton via tiny valves called spiracles. The head, thorax and abdomen are three distinct body segment of the ant (Green, 1967).

*Solenopsis sp. w*orkers are polymorphic. The body is about 1.6-6 mm long but for queens the average is about 6.6 mm long. Head and thorax are yellowish red and the abdomen is black; reproduction organs are darker. Antenna have 10 segments, with 2 segmented club. Thorax lacks spines, profile unevenly rounded. Pedicel is segmented into two. The mandible has 4 teeth (Department of Entomology and Plant Pathology, AUBURN University, 2013).

i. Head

An ant's head contains many sensory organs. Ants have compound eyes made from numerous tiny lenses attached together. Two antennae are attached to the head and the head has two strong jaws. At the front of the head is the mouth. Ants also have a tongue for sucking up liquid food (Department of Entomology and Plant Pathology, AUBURN University, 2013).

ii. Thorax, mesosoma

The thorax is the middle region of the body, to which three pairs of jointed legs are connected. These six legs are used for running and handling food. Ants have special clawed feet that grab onto a surface, so ants can climb trees or walk on the underside of leaves (California academy of sciences, 2013).

iii. Wings

Most queens and the small number of male ants have wings. However, the wings of the queens are shed due to the nuptial fight and visible stubs are left instead of the wings (Department of Entomology and Plant Pathology, AUBURN University, 2013).

iv. Abdomen

The abdomen, also called metasoma has important internal organs, including those of the reproductive, respiratory (tracheae), heart, stomach and excretory systems. Workers of many species have their egg-laying structures modified into stings that are used for subduing prey and defending their nests. In the front part of the abdomen, near the “waist” of the ant is the petiole. This thin section behind the thorax allows the ant to bend while passing through twisting underground tunnels (California academy of sciences, 2013).

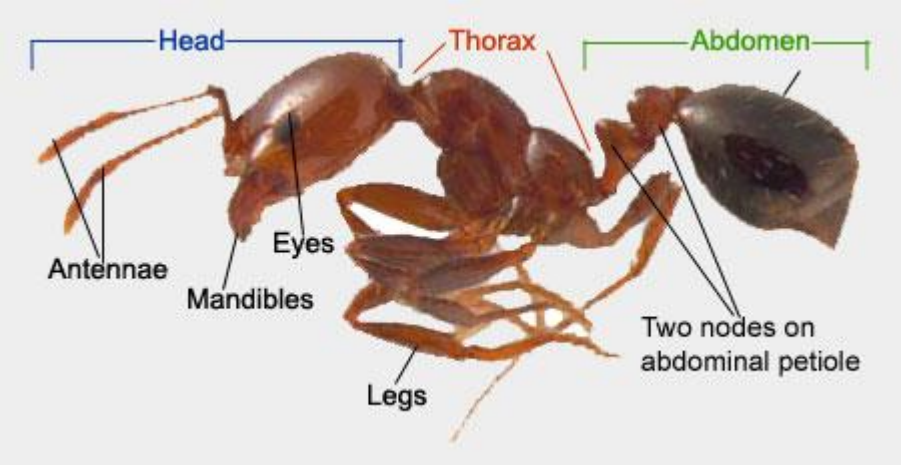

Figure 2.1: Morphology of Ant (eXtension, 2012)

2.1.5 Life Cycle

2.1.5.1 Reproduction and Developmental Stages of Ants

Ants, like all living things, have an individual life cycle. However, because ants are highly socialized organisms– they live in family groups that cooperate to build nests, find food, and raise offspring - they also have a colony life cycle. Ant colonies range in size from just a few individuals to millions. The social lifestyle of ants is a major reason for their success.

Winged males and females (called alates) fly hundreds of feet up from the ground and then mate in flight. Males die soon after mating. Once mated, the female lands, breaks off her wings, and searches for a place to establish **her** new colony, of which she is now queen. A newly mated queen lays about a dozen eggs. A fire ant queen can lay eggs that are fertilized or unfertilized with sperm that she has stored in her body since mating:

- Unfertilized eggs develops into winged male fire ants.
- Fertilized eggs develop into sterile female worker ants or into fertile winged females (eXtension Foundation, 2012).

When the eggs hatch 7 to 10 days later, the larvae are fed by the queen. Later on, a queen fed by worker ants can lay up to 800 eggs per day. Larvae develop 6 to 10 days and then pupate. Adults emerge in 9 to 15 days. The average colony contains 100,000 to 500,000 workers and up to several hundred winged forms and queens. Worker ants exhibit a range of sizes (Department of Entomology and Plant Pathology, AUBURN University, 2013).

Fire ants have four larval stages, or instars. Only the first three larval instars are fed liquids. Solid food, such as parts of insects, are given to fourth instar larvae. The fourth instar larvae break down the solid food into proteins, and the nurse ants then distribute the digested protein, through trophallaxis, to the younger larvae (instars I - III) and to the queen (Bibo, 2012).

Developmental stages of fire ants are eggs, larvae, and pupae (collectively referred to as brood).

- Eggs are spherical and creamy white.
- Larvae are legless, cream-colored and grub-like, with distinct head capsules.
- Pupae resemble worker ants and are initially creamy white, turning darker before adult ants emerge (eXtension Foundation, 2012).

Figure 2.2 Specimens of Fire Ant Developmental Stages (Drees, 2010)

2.1.6 Behaviour and Ecology

A fire ant queen can live for 7 years and produce as many as 1,000 eggs per day. The queen influences the colony by secreting chemicals called pheromones**.** Single queen fire ant colonies (monogyne colonies) have a one fertile queen that lays all the eggs in the colony. Workers in single queen colonies are territorial (Bibo, 2012).

Multiple queen fire ant colonies (polygyne colonies) have multiple fertile queens that share egg laying and colony leadership. Workers from multiple queen colonies move freely from one mound to another, which has resulted in a dramatic increase in the number of mounds per acre (eXtension Foundation, 2012).

A mature colony can contain up to 400,000 female worker ants. Worker ants generally live about 5 weeks, Worker ants are wingless, sterile females. They protect the queen by defending the nest from intruders, by feeding the queen only food that the workers have eaten first, and by moving the queen from

danger. They also forage and care for the developing brood (Department of Entomology and Plant Pathology, AUBURN University, 2013).

Fire ants build a dirt nest or mound, which can be up to 40 cm high. The shape and size of the nest varies depending on soil type and colony size. An unusual feature of the mound is that it has no obvious entry or exit hole. The ants enter and leave the mound via underground tunnels which radiate outwards from the nest. These tunnels can be up to 30 m long (Bibo, 2012).

Fire ant larvae that receive more food become winged females instead of workers. The winged forms, or reproductives live in the mound until their mating flight, which usually occurs in the afternoon soon after a rainy period. Mating flights are most common in spring and fall (Department of Entomology and Plant Pathology, AUBURN University, 2013).

When a fire ant colony or mound is disturbed, worker ants rush to the surface to defend the colony by biting and stinging while the queen(s) quickly crawl downward to avoid harm (eXtension Foundation, 2012).

Most ants travel by walking. Some species are capable of leaping The oldest worker ants are called foragers. Foraging ants travel distances of up to 200 metres (700 ft) from their nest and scent trails allow them to find their way back even in the dark. In hot and arid regions, day-foraging ants face death by desiccation, so the ability to find the shortest route back to the nest reduces that risk. Many animals can learn behaviours by imitation, but ants may be the only group apart from mammals where interactive teaching has been observed (Wittlinger et al, 2006).

Fire ants can be beneficial. They are omnivores. They feed primarily on insects and arthropod pests, which can reduce the need for insecticides in commercial agriculture. In urban areas fire ants feed on flea larvae, chinch bugs,

cockroach eggs, ticks and other pests (Department of Entomology and Plant Pathology, AUBURN University, 2013).

Figure 2.3 Fire ant workers tending a queen (Vinson, 2010)

2.1.7 Medical Importance of *Solenopsis sp.*

Encounters with fire ants usually involve dozens of ants moving quickly and undetected. They tend to all sting at once and ants can sting repeatedly. Fire ants may attack with little warning. After firmly grasping the skin with its jaws, the fire ant arches its back as it inserts its rear-end stinger into the flesh, injecting venom from the poison sac. It then pivots at the head and typically inflicts an average of seven to eight stings in a circular pattern. Fire ant venom is unique because of the high concentration of toxins, which are responsible for the burning pain characteristic of fire ant stings (More, 2011).

Each year, fire ants sting more than one half of the population in endemic areas of the Southeasten United States. The rate is probably much higher for

those with outdoor hobbies and occupations, such as outdoor sports and gardening. Fire ant stings can cause a variety of medical problems, including increasing numbers of hypersensitivity reactions, secondary infections, neurologic complications, and even death (Ralston, 2012).

Fire ant sting reactions range from localized itching and swelling with pustule formation to severe, life-threatening anaphylaxis.

Symptoms may include:

- Swelling, redness, itchiness, and pain around the site of bite
- Pus-filled blisters that last 3 - 8 days
- Possible scab at the area of the bite that lasts 3 - 10 days

Those allergic to fire ant venom may also have

- Difficulty breathing
- Rapid heart rate
- Throat swelling (Steen and Schwartz, 2008)

Anaphylaxis, also known as a whole-body allergic reaction, can occur in about 1% of people who are stung by fire ants. This reaction can be severe and even life threatening. Symptoms of anaphylaxis from fire ant stings may include any of the following:

- itching all over
- hives or swelling that spreads from the site of the sting
- flushing
- runny nose, sneezing or post-nasal drip
- itchy/watery eyes
- swelling of the lips, tongue or throat
- shortness of breath, wheezing or coughing
- stomach cramping, nausea, vomiting or diarrhea

- lightheadedness, fast heart rate, low blood pressure or passing out
- sense of panic
- metallic taste in the mouth (More, 2011)

2.1.7.1 Treatment of Stings

Cool compresses and oral antihistamines are recommended for mild reactions. Corticosteroids can be used topically or intralesionally for anti-inflammatory effect (Ralston, 2012).

First aid for fire ant stings

- A cold compress is applied to relieve the swelling and pain.
- The affected area is gently washed with soap and water and the blister is left intact.
- If the patient is allergic to insect stings or experience symptoms of allergy, medical attention should be sought immediately (Ralston, 2012).

Large local reactions can be treated with over-the-counter anti-inflammatory medications, such as Motrin (ibuprofen), as well as antihistamines, such as Claritin (loratadine) or Benadryl (diphenhydramine). Ice can be applied to the area, and the area can be elevated to decrease swelling. Lastly, a topical steroid, such as hydrocortisone 1% cream, can be applied to the local reaction site (More, 2011).

The treatment of anaphylaxis from fire ant stings is essentially the same as treatment of whole-body reactions to flying stinging insects. This includes the use of injectable epinephrine (More, 2011).

Allergen immunotherapy (allergy shots) has proven to be an extremely effective form of treatment for individuals at risk of insect sting anaphylaxis. Any fire ant sting victim who has suffered a systemic allergic reaction to a fire ant

sting should be referred to a trained allergist for skin testing and evaluation for immunotherapy. Treatment goals are to:

- prevent life-threatening reactions;
- reduce complications;
- and alleviate anxiety (More, 2011) .

2.2 Red Pepper, *Capsicum annuum*

Red pepper is a plant which belongs to the family *Solanaceae* that includes eggplant and tomatoes. It is originated from southern North America and northern South America. Nowadays, the plant is widely cultivated in all tropical parts of the world. The species, *Capsicum annuum* includes a wide variety of shapes and sizes of peppers, both mild and hot, ranging from bell peppers to chili peppers. Although the species name *annuum* means “annual” (from the Latin *annus* “year”), the plant is not an annual and in the absence of winter frosts can survive several seasons and grow into a large perennial shrub (Latham, 2013). Common names of *Capsicum annuum* other than ‘red pepper’ are chilli pepper, bell pepper, paprika, cayenne, halapenos, hot pepper and Christmas pepper.

2.2.1 Taxonomy

Taxonomy of red pepper, *Capsicum annuum* is described as follow (Pitojo, 2001):

Kingdom : *Plantae*

Division : *Spermatophyta*

Subdivision : *Angiospermae*

Class : *Dicotyledoneae*

Subclass : *Sympetalae*

Order : *Tubiflorae (Solanales)*

Family : *Solanaceae*

Genus : *Capsicum*

Species : *Capsicum annuum*

2.2.2 Morphology of Red Pepper

i. Root

The root of red pepper plant is strong and consists of main root, branches and root fibers. The length of the root may become about one meter in the soil for a one-year-old plant (Pitojo, 2001).

ii. Stem

The stem is smooth and woody at the base. The length of red pepper plant is approximately from 50cm to 150 cm and the stem immediately branches above the surface of the ground. The colour of the branches ranges from green to violet depending on different kinds of the plant (Pitojo, 2001).

iii. Leaf

Red pepper plant has simple single leaves. The leaves are oblong, smooth and hairless. Leaf length ranges from 5 cm-12 cm and width 1.5 cm-4 cm, and the length of the petiole ranges from 1 cm- 1.25 cm. The leaves are green to purple depending on varieties (Pitojo, 2001).

iv. Flower

Pepper plants have perfect flowers. The flowers are solitary, rarely in pairs, pure white to bluish white, very rarely violet in colour. The stalks emerge from the armpit of leaves, hanging or standing there. Flowers have five petals, forming a diameter about 8mm- 15mm and are of different shapes like a star,

trumpet, funnel or crown. There are five to six pieces of elongated-shaped stamens with bluish heads (Pitojo, 2001).

v. Fruit

The berries are green, maturing into yellow, orange to red grading into brown or purple, pendent, rarely erect, very variable in size (up to 20 cm long and 10 cm in diameter), shape and pungency and sometimes lobed (Krishna De, 2004).

vi. Seed

The seeds are white or cream to yellow, thin, almost circular, having long placental connections (Krishna De, 2004).

Figure 2.4 *Capsicum annuum* (Dave's Garden, 2006)

2.2.3 Uses of *Capsicum annuum*

2.2.3.1 Culinary Uses

Peppers are very often used as a bulking agent in ready-made meals and take-away food, because they are cheap, have a strong flavour, and are colorful. The colorful aspect of peppers increases the visual appeal of the food, making it more appetizing. Foods containing peppers, especially chili peppers, often have a strong aftertaste due to the presence of capsinoids in peppers (Grubben & Denton, 2004).

2.2.3.2 Medicinal Uses

Capsicum annuum is used for numerous medicinal and therapeutic purposes. Some of them are using of capsicum in cough drop formulations, analgesics, thermo slimming cosmetic compositions, ache and pain compounds and arthritis compositions (Neumann, 1999).

2.2.3.3 Insecticidal Uses in Agriculture

Capsicum annuum comprises an effective activity-enhancing amount of capsaicin or other capsaicinoids. These compositions exhibit synergistic effects against numerous insects, including bud worms, boll worms, cabbage loopers, army worms, beet army worms, and beetles, and are especially effective on cotton, soybeans, common garden vegetables, and flowers, when sprayed on the insect or its habitat as an aqueous solution, suspension, or emulsion. Larger crop stands may be effectively treated by aerial spraying from the usual crop-dusting airplane (Neumann, 1999).

2.2.4 Active Substance of Red Pepper, *Capsicum annuum* which play a role as an insecticide

2.2.4.1 Capsaicin

Capsaicin is the active component which is extracted from red pepper, *Capsicum annuum.* Red peppers have capsaicinoid levels of 600-13,000 ppm (parts per million). Therefore, they have very strong pungency and that is the reason why red pepper, *Capsicum annuum is used to* deter and kill fire ants. Capsaicin and several related compounds are called capsaicinoids. Capsaicin is the main capsaicinoid in chili peppers, followed by dihydrocapsaicin. These compounds are responsible for the strong pungency of the pepper. Capsaicin produces a burning sensation to any tissue that it comes into contact with (Tomita and Endo, 2007).

Chemical name of capsaicin is 8-Methyl-*N*-vanillyl-*trans*-6-nonenamide. Capsaicin is believed to be synthesized in the interlocular septum of chili peppers by addition of a branched-chain fatty acid to vanillylamine; specifically, capsaicin is made from vanillylamine and 8-methyl-6-nonenoyl CoA, where CoA means Coenzyme A (Fujiwake et al., 1980). Capsaicin is a whitish powder which is soluble in alcohol but insoluble in cold water, which is why drinking water to help alleviate the burning won't work (Neumann, 1999).

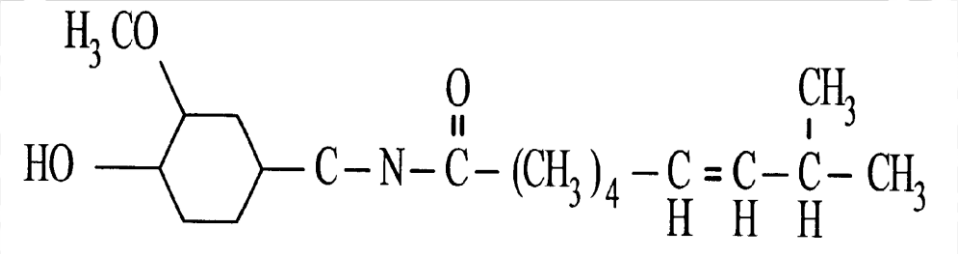

Figure 2.5 Chemical structure of Capsaicin

Physical / Chemical Properties:

- Vapor pressure : Very low
- Octanol-Water Partition Coefficient (K_{ow}): 3.04
- Henry's constant : 1 x 10^{-13} atm·m^3/mol at 25 °C
- Molecular weight : 305.462 g/mol
- Solubility (water) : 10.3 mg/L at 25 °C
- Soil Sorption Coefficient (K_{oc}) : 1.10 x 10^3 (Bethesda, 2006)

Toxicity of capsaicin can cause skin irritation. Little absorption occurs across the skin. Capsaicin can severely irritate the eyes, and was found to cause corneal lesions in rats and mice. Capsaicin temporarily causes broncho-constriction, coughing, nausea, and incoordination in the upper body in humans following inhalation. People suffering from asthma and other respiratory diseases may be more sensitive to capsaicin than other individuals. Severe over-exposure to pure capsaicin can result in death; the lethal dose (LD_{50} in mice) is 47.2 mg/kg (Lewis, 2000).

2.2.5 Mechanism of Action of *Capsicum annuum* Extract as an Insecticide

In insects, capsaicin's toxicity appears to be through metabolic disruption, membrane damage, and nervous system dysfunction. Capsaicin has also been shown to repel insects as well as kill them. By contacting any living organism such as ants, termites, spiders, etc. with an aqueous solution containing any operable amount of capsicum, the cells of the body part of the insect or other living organism in contact with the killing solution will be disrupted and the organism will be killed. Spraying and injecting the killing solution into walls, ceilings, foundations, soil around foundations and tree stumps, etc., will rid those areas completely of an existing infestation (Neumann, 1999).