INTRODUCTION
Over the past four to five decades, insect pests have been mainly controlled with synthetic insecticides. Most of these insecticidal compounds fall within four main groups, viz., organochlorines, organophosphates, carbamates, and pyrethroids. Among these major classes in use today are organophosphates and carbamates (Ware, 1982; Dorow, 1993). Increased over reliability and non judicious use of synthetic chemicals as insecticides has lead to a wide spectrum of issues like insect resistance to pesticides, resurgence of pests, negative effects on non-target organisms (Rembold, 1984; Franzen 1993; FAO, 1992), non biodegradability, accumulation of residues in the soil and agricultural products. Conventional synthetic pesticides are not only expensive and in many cases have only produced moderate results along with major ecological damage (Franzen, 1993) but also require special safety procedures and equipment during production and application because of the exposure risks for humans, the environment and food (Franzen, 1993; FAO, 1992; Mahapatra and Gupta, 1998). The toxicity of conventional synthetic insecticides is mainly restricted to neuro-muscular function (Ware, 1982) which can have deleterious effects on the neuromuscular function of the vertebrates including humans that are exposed.

Henceforth, there has been enough pressure on the farmers to reduce or completely eliminate the usage of such synthetic pesticides in agriculture. The use of organochlorine insecticides has been banned in developed countries (Rembold, 1984).

This concern has encouraged researchers to look for better alternatives to synthetic pesticides (Rembold, 1984).

One of the solutions thought of to counter this problem is the use of biodegradable chemicals such as growth regulators, antifeedants, and oviposition deterrents of natural origin. Plants perhaps, are the most promising source of such compounds
that can be used in pest control. The plant extracts are generally pest-specific and are relatively harmless to non-target organisms including humans. In many cases, these materials are locally available and affordable (Childs et al., 2001). The supply of natural insecticides could also be made continuous at a cheaper rate by regular cultivation making it more economical. Besides being not only safe and less toxic they are also easily biodegradable in nature without leaving any residual toxicity in the environment (Jacobson, 1975). Furthermore, unlike conventional insecticides that are based on a single active ingredient, plant-derived insecticides comprise an array of chemical compounds which act collectively on both behavioural and physiological processes. Thus the chances of pests developing resistance to such substances are less likely (Saxena, 1987).

Many of the higher plants possess secondary metabolites, such as flavones, coumarins, rotenoids, tannins, terpenoids, quinines, limonoids, and alkaloids etc which are concentrated in different parts of the plants that come in hand for defense against microbes, herbivores and mammals. These secondary metabolites possess a number of biological properties of repellence, feeding deterrence, growth disruption, mating disruption, oviposition disruption, fecundity reduction, insecticidal, and ovi-cidal activities on insects and thus can be successfully employed in plant protection.

Botanical pesticides possess an array of properties including insecticidal activity, insect growth regulation, toxicity to insects, mites and other agricultural pests (Prakash and Rao, 1984, 1986; Prakash et al., 1997, 1989, 1994). Low mammalian toxicity, no reported development of resistance among insects, no pest resurgence, and no adverse effect on plant growth, negligible application risks and easy availability are the advantages. The pests of crops applied with botanicals like neem products remain starved, become weak and are prone to be predated or parasitized by natural enemies or otherwise die. Thus botanical pesticides are more reliable and
ecologically sound alternatives to synthetic insecticides in keeping insect pest populations under check (Revanna, 2009).

In fact, the use of plant products in insect control is a very ancient practice from time immemorial (Krishnamurthi, 1943). As many as 2121 plant species with insecticide properties (Jacobson, 1975), 384 antifeedant, 297 repellents, 27 attractants and 31 growth inhibiting properties have been reported so far (Revanna, 2009). Identification of many more are in the pipeline. More than 68 neem based formulations are commercially available in India and this is likely to increase in the near future (Revanna, 2009). Of the estimated 3,50,000 plant species worldwide (Revanna, 2009), very few, numbering about 2400 species, have shown to have some insecticidal property and most remain unutilized for pesticide purposes (Dev and Koul, 1997). On the whole, phytochemical-based biopesticides offer a unique opportunity for developing countries to explore and develop natural biopesticides for crop protection (Schmutterrer 1992).

In the present study an effort was made to study the effect of extracts of different aerial parts of *Calendula officinalis* L. on the physiology of a lepidopteran pest, *Spodoptera litura* Fab under laboratory conditions.

The compounds from Compositae plants and especially Calendula species have been shown to have insect antifeedant and growth inhibitory activity on various insects like green leafhopper, brown planthopper, and seed beetles. Besides antifeedancy in *Pieris brassicae* (Wawrzyniak, 1996) recent research has also demonstrated their larvicidal, ovicidal, and oviposition deterrent effects in *Liriomyza helianthi* Spencer (Claudio and Stephen, 1998), *Culex pipiens* (Elyassaki & M. M. El Sayed, 1996), *Oncopeltus fasciatus* Dallas (Maja Alexander & August Dorn, 2007). Various toxic effects on adults of the rice weevil *Sitophilus oryzae* (L.), the lesser grain borer *Rizopertha dominica* (F.) and the red flour beetle *Tribolium castaneum* (Herbst)
(Yasser, 2000) and decreased fecundity in Mediterranean fruit fly \textit{Ceratitis capitata} Wied (Hussein et al (2005) have also been demonstrated.

The pest under consideration, \textit{Spodoptera litura} (Fabricius) is the cosmopolitan insect species. It has a number of common names including the tropical armyworm, armyworm, cluster caterpillar, rice cutworm, and cotton leafworm or tobacco cutworm. \textit{S. litura} was first recorded from New Zealand as a pest of tobacco and it has appeared in significant numbers in home garden and on crops across the globe (Cottier and Gourlay, 1955). It is a serious polyphagous pest that attack many economically important plants. The host range of this species covers over 40 families of economic importance crop species (Salama et al., 1970).

In the early instars the larvae are gregarious in habit and hundreds of them are seen mining on soft tissues of a single leaf. The young larvae hang on silken threads produced from saliva and migrate to other leaves. In late instars, they become solitary and get distributed on leaves cutting holes on them by feeding. The grown up caterpillars also act as cutworms cutting the tender seedling of young plants in field. Under favorable conditions, if left unchecked the entire plantation are completely wiped out by this pest. The extent of damage varies from 80-100\% in tobacco nurseries and 10-15\% in planted crop (Prakash, 1997). In heavy infestation it can seriously defoliate a crop.

The pest emergence is found to be associated with food availability and suitable climatic condition where it attacks not only leaves but tunnels in the stem of the plant. Mature larvae present a serious threat because of their extensive eating habits and the large numbers during an outbreak. The outbreak of this insect generally occurs with a good rainfall after a long dry spell (Boardman, 1977). These outbreaks suggest the necessity of adopting a well planned strategy for this pest. With the advent of synthetic insecticides, chemical control has become dominant in the pest
management on crops. Several workers have tested the efficacy of various types of insecticide against *S. litura* and recommended insecticides like cypermethrin, endosulfan, etc for its control. But the use of insecticides is associated with problems like development of insecticide resistance in pest, toxicity to beneficial insects like parasitoids and predators and toxic residues in crop produce affecting the human health. Resistance in *Spodoptera* has been demonstrated on larvae reared on cotton to all types of insecticides viz., organochlorines, organophosphates and synthetic pyrethroids (Prakash, 1997). Hence to mitigate these problems efforts have to be made towards ecological safe natural insecticides for this pest.

*Calendula officinalis* Linn (Asteraceae), commonly known as Pot Marigold is traditionally used for the treatment of different kinds of human diseases (Nadkarni, 1982, Brown & Dattner, 1998, Grover & Yadav, 2004 and Christopher, 2005), because of the broad area of biological activities like anti-inflammatory, anti-mutagenic, diuretic, antispasmodic activities. It is used in treatment of gastrointestinal, gynecological, eye diseases, wound healing, and skin diseases like psoriasis, leprosy etc (Horvath & Ferenc, 1992; Zahra et al., 2000 and Harrison & Dorothy, 2003). Apart from its medicinal properties this plant, as some of its relative species that are active against pest insects, may also have stored some such properties that could be used against *Spodoptera litura* a polyphagous pest.

With this framework, studies on isolation and characterization of factors from *Calendula officinalis* that affect the physiology of *Spodoptera litura* were initiated. The major objectives of the study were as follows:

1. To understand the mechanisms underlying the life cycle and reproduction in *Spodoptera litura* that is a serious agricultural pest.
2. To extract the phytochemicals from the aerial parts viz., leaf and flower of *Calendula officinalis*.
3. To evaluate the influence of these extracts on different physiological parameters of the pest by bioassays.

4. To isolate and characterize the bioactive compounds against the pest.

In the long term perspective, once such factors are isolated and characterized from the plant, it would be possible to deploy them or their analogues to influence the behavior and physiology of the insect which can be an appropriate approach in pest management.

Several questions arose during the implementation of the above objectives which led to investigate the same. They include:

1. Standardization of an efficient method to establish insect colonies since mass rearing was necessary for studying the physiology of the insect.

2. Study of life history characteristics of the pest so that it would be possible to interfere at the appropriate stage of the lifecycle.

3. Identification of suitable physiological parameters of the insect for bioassay.

4. Establishment of an efficient bioassay technique for elucidating the influence of plant extracts on the physiology of the pest.

5. Isolation and characterization of the bioactive compounds against the pest.

An extensive literature survey cited in the next chapter was carried out primarily to understand the status of research at both national and international level, on botanical pesticides and their role in different physiological attributes of the pests, later to identify the objectives and finally to design the experiments. An effort was also made to understand similar work carried out on other insects, which may help in appreciating the current investigation.