1. INTRODUCTION

Agriculture is the back bone of the Indian economy. Nearly 75% of the rural areas of Indian villagers are depending on agriculture. The Ministry of Agriculture and Co-operation, Government of India, New Delhi estimated an annual growth rate (%) for 2001-2006 that required 2.35% of rice, 2.22% of wheat, 1.36% of sorghum, 2.00% of maize, 4.43% of chickpea, 4.28% of pigeon pea, 2.51% of groundnut, 2.13% of rapeseed and mustard, 3.20% of vegetables, 6.04% of fruits, 3.78% of cotton and 3.80% of sugarcane in order to feed the growing population. The amount of food production is greatly deteriorated by the farmer`s enemies (pests and diseases) either directly by causing losses to the crops in the field or indirectly by causing disease and reducing the crop yield. According to the United States Census Bureau (USCB), the total world population is 7.18 billion. The requirement of feed this population is double the amount of food production, this will require a threefold increase in the annual use of fertilizers and much more extensive use of pesticides (Kannaiyan, 2000). The green revolution in our country, while ushering the much-needed self-sufficiency in food production also paved the way for intensive use of harmful chemical pesticides.

1.1 Chemical pesticides and their impacts

Application of chemical pesticides minimized threat from pest manifestation by rapid knock down effect on /them, *albeit* with little consideration to the quality (nutritional contents) of the crop, and quality of agro-residues. The most striking feature of utilization of synthetic pesticides in India is about 50% of the total pesticides produced are used on cotton crop alone, followed by about 17% on rice. It has been estimated that hardly 0.1% of the agrochemical used in crop protection reach the target pest leaving the remaining 99.9% to enter the environment and cause hazards to non-target organisms. However, indiscriminate use of pesticide over a long period has not only proved to be harmful to soil micro-flora, animals and humans, but also it contributed to a number of side effects, *viz.* development of resistance by the insects/weeds/pests, resurgence and outbreak of new pests, toxicity to non-target organism, presence of non permissible level of pesticide residues on seeds, vegetables, fruits and border alteration in dynamics of pest species population, cumulatively causing poor soil fertility, hazardous effects on environment endangering the sustainability of ecosystem (Kannaiyan, 2000). Higher dose and repeated frequency of applications has also caused about one million people to suffer every year from pesticide poisoning. These dreadful facts demand ecofriendly and environmentally safer alternate methods for crop protection.

1.2 Botanicals in Integrated Pest Management

Integrated Pest Management (IPM) has inherent scope in planning, developing and accepting eco-friendly technologies for application aimed at controlling pests on sustainable basis. Many of the plant-derived materials are safer and effective against diseases, nematodes and other organisms in addition to phytophagous insects (Abdul Kareem, 1999). The wide range of behavioral and physiological effects, the possibility of developing resistance in insects to these pesticides is very low. Integration of the botanicals with IPM is environmentally safer approach for controlling insects.

1.3 Botanicals and their advantages

Plants and insects have co-evolved over millions of years; plants have accumulated specific secondary metabolites to counteract insect damage. These bioactive secondary metabolites act as insecticides, antifeedants, insect growth regulators, juvenile hormones, ecdysones, repellents, attractants, arrestants, etc. (Kannaiyan, 2002). From the above, the activities of the plants can be considered as important alternative source for the chemical pesticides. Apart from the various activities, the plant derived chemical compounds have the following advantages.

Plant based pesticides are economically viable and ecologically safer than the conventional synthetic pesticides. Unlike chemical pesticides, most of the plants have more than one chemical compound, which possess the biological activity. These chemicals may exert a single biological effect or may have diverse biological effects. Hence, the chances of developing quick resistance to different chemicals are unlikely.Poor and marginal farmers suffering from increasing cost and hazards of the synthetic pesticides, can grow their own pesticide yielding plants. Plant based Pesticides are easily biodegradable in nature, economically viable and environmentally safer.

1.4 Scenario of Botanical Research

Worldwide attention now focuses towards alternative methods of pest control, which is derived from naturally available resources. In recent years, great emphasis is given on the use of natural products, which are non-toxic, safe, low cost and biodegradable than the conventional control of insects by synthetic pesticides. Earlier studies have indicated that antifeedant compounds derived from seeds, flowers, fruits, leaves and roots of the plants could be used as effective bio-compounds against the growth and metamorphosis of the noxious insects. So for, 6,000 alkaloids, 3,000 terpenoids, several thousands of phenylterpenoids, 1,000 flavonoids, 500 quinones, 650 poly acetylenes and 4,000 amino acids have been reported and many of them have protected the plants from insect and pathogens (Abdul Kareem, 1999). Even though, India is one of the mega plant biodiversity countries, the plant kingdom is still an untapped reservoir of new molecules having biopesticidal potential. Plant species of the family Meliaceae and Rutaceae have shown promising insecticidal activity which is contributed mainly by limonoids similar to that of Azadirachtin. Similarly, plumbagin a natural bioactive principle present in many plants belonging to families like Plumbaginaceae, Droseraceae, Ebenaceae, Euphorbiaceae, Crucifereae and Iridolceaes, has shown substantial promise in insect control. In total, nearly 2000 plant species are known to possess antimicrobial and insecticidal phytochemicals. However, so for, neem based pesticide alone is commercialized and available for large-scale utilization. Further the continuous efforts for searching botanicals against insect pest will lead to identify and isolate the new compounds, which will be useful for future insect pest management.

1.5 Importance of storage of agricultural products

Most agricultural commodities are produced seasonally and their harvesting is normally done during a short period of three to five months, while their consumption is throughout the year. For this reason, storage becomes necessary and it is normally done for extended periods of more than six months in order to maintain a uniform supply of food for consumption, for the domestic and export market and to provide a buffer stock for contingencies such as drought, floods and war.

Stored products include any materials, which may be dried, and stored for future use as foodstuffs, industrial raw materials, medicines, or a planting materials and these include cereals, pulses, dried seeds and root crops (Chomchalow, 2003). Insect pests of the stored products are problematic throughout the world, because they reduce the quality and quantity of the grains. The reasons for their widespread presence range from evolutionary adaptations (morphological, physiological and behavioural) to the actions of humans who transport them throughout the world and offer a protected habitat (Pugazhvendan *et al.,* 2009).

1.6 Global scenario of grain loss and infestations by storage pests

Storage of grains is a part of the post-harvest system through which food material passes on its way from field to consumer. It is generally accepted that 5–15% of the total weight of all cereals, oilseeds and pulses is lost after harvest (Anonymous, 1989). About 10–40% of produced grains are lost every year due to insect damage in developing countries alone, resulting largely from the lack of modern storage technologies (Shaaya *et al.,* 1997). The global post-harvest grain losses caused by insect damage and other bio-agents range from 10–40% (Raja *et al.*, 2001; Papachristos and Stamopoulos, 2002). The estimated global post-harvest losses caused by insect damage, microbial deterioration and other factors are of the order of 10 - 25% (Matthews, 1993). Annual post-harvest losses resulting from insect damage, microbial deterioration, and other factors are estimated to be 10–25% of production world wide. (Mohan and Fields, 2002).

Insect pests cause significant damage in stored grain in Brazil and losses have been estimated to be about 10% of total grain stored each year (Anonymous, 1993). Canada annually produces 60 mt (Million tonnes) of grains and oilseeds (Canada Grains Council, 2003), and has a reputation for providing high quality grain without insect infestations. However, grain storage losses caused by insect infestation do occur in Canada. Latin America produces nearly half the world's supply of dry beans, *Phaseolus* spp. (Leguminosae) (Cardona and Kornegay, 1999). Almost 80% of Latin American beans are produced on small-scale farms. Post-harvest crop losses are predominantly caused by coleopteran species from the family Bruchidae.

Maize is an important source of carbohydrate in the tropics (Baba, 1994). In Ghana, annual production of maize is about 932,000 tonnes (Owusu-Akyaw, 1991). The maize weevil, *Sitophilus zeamais*

Motschulsky is a serious pest of stored maize, causing considerable losses. Prempeh (1971) estimated that out of a total annual harvest of 250–300,000 tonnes of maize in Ghana, about 20% was lost to insect pests. In some cases total loss can occur. On the worldwide basis, as much as 10% of the stored cereal grain is estimated to be lost through insect infestation (Larry, 2000). In Ethiopia, losses ranging from 20–30% are common in stores due to insect pests (Abraham, 1991; Emana, 1999).

Post-harvest losses by storage insect pests such as the maize weevil, *Sitophilus zeamais* Motschulsky continue to pose a major problem in Africa (Markham *et al.,* 1994). 100% of cowpea seeds are infested after 3 - 5 months of storage in West Africa. Tanzubil (1991) found that this insect can damage 100% of stored seeds causing weight losses of up to 60%. After six months of storage, losses in terms of perforated seeds can reach 90% (Seck *et al.,* 1991). Annual losses of cowpeas in Nigeria due to *Callosobruchus maculatus* have been estimated to 2900 tonnes (dry weight) (Caswell, 1973). The common pulse weevil *C. maculatus* alone caused an annual loss of 24% of stored pulses in Nigeria (Caswell, 1968). In the Western highlands of Cameroon, losses in stored maize due to storage insects range between 12% and 44% during the first six months of storage (Fontem, 1982; Ouattara, 1981). It is therefore necessary to reduce such losses by controlling pests on stored grains.

Maize is the staple food of over 80% of Kenya's population of over 24 million. Although it is grown on large farms, especially in the Rift Valley province, more than 90% of this crop is produced on small scale farms (Odhiambo, 1988). Post-harvest yield losses vary widely (Schulten, 1988), but losses are generally around 4–5% per annum of maize stored on-farm in Africa (McFarlane, 1988a). In Sudan, storage losses of 2.5–7.6% was recorded on sorghum (Seifelnasr, 1992); whereas weight losses ranged from 6.1–14.3% was reported for sorghum grain that stored for 4 months in traditional granaries in Kenya (Nyambo, 1993).

1.7 Indian scenario of grain loss and infestations by storage pests

India is the largest producer of pulses in the world accounting for 28% of the global production. The annual production of pulses in India has fluctuated between 12 million metric tonnes (MMT) and 14 MMT within the last four decades, coming from around 24 million hectares (nearly 35%) of land under their cultivation (Anonymous, 1998). In India, 12.5 MMT of edible legumes are produced every year and nearly 18.6% of cowpeas are damaged by bruchids during storage (Agarwal *et al.,* 1988). Insects often cause extensive damage to stored grains and grain products and this may amount to 5–10% in the temperate zone and 20–30% in the tropical zone (Nakakita, 1998). In India, post harvest losses caused exclusively by insect pests are 12% (Mohan, 2003).

Caswell (1981) reported a loss of approximately 50% of cowpeas in storage for 3 or 4 months is due to infestation by *C. maculatus*. The projected food demand for 2025 will require the yield of millets to rise from 2.5– 4.5 t ha-1(1 tonne per hectare) (Kothari *et al.,* 2005). Apart from lack of irrigation and fertilizer for millet cultivation, insect pests and fungal and bacterial diseases cause huge losses in many parts of the world. Pest and/or pathogen attack causes 10–40% reduction in crop yield, depending on the geographical location (Repellin *et al.,* 2001). The estimated loss of sorghum crop due to pests and pathogen attack is 30% (Reddy and Zehr, 2004).

1.8 Control of stored grain pests

Stored products of agricultural origin are attacked by more than 600 species of beetle pests, 70 species of moths and about 355 species of mites causing quantitative and qualitative losses (Rajendran, 2002) and insect contamination in food commodities is an important quality control problem of concern for food industries. Stored product insect control is currently based mainly on the use of two broad categories of insecticides: residual insecticides and fumigants. The development of resistance to these substances and the demands of consumers for residue free food have lead researchers to evaluate the use of alternative control methods, which do not leave residues on the product and are generally safe for the environment. Insect pathogens, such as entomopathogenic fungi, bacteria, viruses, protozoa and nematodes offer many advantages, such as high efficacy and compatibility with other IPM methods and thus are considered to be among the most promising alternatives to chemical-based insect control (Moore *et al.,* 2000).

Insect pests have mainly been controlled with synthetic insecticides in the last fifty years. The protection of stored grains from insect damage is currently dependent on synthetic pesticides. Most insecticidal compounds fall within four main classes, the organochlorines, organophosphates, carbamates and pyrethroids. There are problems of pesticide resistance and negative effects on non-target organisms including man and the environment. The use of organochlorine insecticides have been banned in developed countries and alternative methods of insect pest control are being investigated.

Fumigation is one of the major chemical methods to control stored-product insect infestations worldwide. Fumigation is the method of choice for many stored-grain managers because it is effective against all life stages, inexpensive, rapid and leaves minimal residues (Van Someren Graver, 2004). Currently, phosphine and methyl bromide are the products most widely used (Bond, 1984; Fields and White, 2002; Lee *et al.,* 2004;

Emekci, 2010). Carbon- di- oxide and Sulfuryl fluoride are also registered for fumigation of stored grain in several countries. Methyl bromide has largely been phased out in developed countries and it is slated to be phased out in the rest of the world by 2015, because it is an ozone depleting substance (TEAP, 2000; Fields and White, 2002). Phosphine is not effective against some insect populations in India, Australia and Brazil, because of resistance (Bell and Wilson, 1995; Benhalima *et al.,* 2004; Collins *et al.,* 2005; Pimentel *et al.,* 2009). Carbon- di-oxide requires high temperatures and high concentrations to control insect populations (Soderstrom *et al.,* 1992). Sulfuryl fluoride is being used as a replacement for methyl bromide, but eggs require high doses or long durations to be effective (Kenaga, 1957; Baltaci *et al.,* 2009).

Although effective fumigants and contact synthetic insecticides are available, there is a global concern about their negative effects such as ozone depletion, environmental pollution, toxicity to non-target organisms, pest resistance and pesticide residues (Kostyukovsky *et al.,* 2002a; Ogendo *et al.,* 2003). Currently national governments, food industries and exporters rely heavily on fumigation as a quick and effective tool for insect pest control in food commodities (Rajendran, 2001). Despite their significance in assuring quality, several fumigants have been withdrawn or discontinued on grounds of environmental safety, cost, carcinogenicity, ozone depletion and other factors (Rajendran, 2001; Shaaya and Kostyukovsky, 2006).

While reviewing the literature pertaining to the storage pests, there is paucity of information on *Tribolium castaneum* are available. Various work related to storage pest control b plant essential oils and plant extracts were reviewed. Ahmed *et al.,* (2000) tested an extract of *A. calamus* and cypermethrin for their effect on the enzymatic activity of *S. oryzae.* Alkaline-phosphate activity was reduced to 11.11 and 13.13% by a treatment with LC_{50}'s of *A. calamus* extract and cypermethrin, respectively. Chander *et al.,* (2000) has reported that nine insect repellents, including acetone extracts of some local plants, *viz*., Sweet flag rhizomes, kut root, 'curry' (*Murrayapaniculata*) leaf, kinnow peel, turmeric rhizomes, crude mustard oil, two commercial neem formulations and one synthetic pyrethroid (cypermethrin), were evaluated. As an insect repellent, cypermethrin was the most effective followed by the 'kut' root turmeric, nimbicidin, *Murraya*-extract, *Acorus calamus*-extract and *S. lappa*-extract. Treatments of mustard oil and 'kinnow' peel-extract were the least effective, extracts of *Murraya*, turmeric, *S. lappa* and nimbicidin, showed a good repellence activity against the test insect, even after three months of ageing, under laboratory conditions.

Umoetok (2000) investigated the toxicity of the powdered *A. calamus* to three species of insect pests, *viz*., *S. oryzae, T. castaneum* and *R.dominica*. *A. calamus* was applied at six doses of wheat grains. The results indicated that only *S. oryzae* and *R. dominica* were susceptible to the test-products and 100% of *S. oryzae* and 90% of *R. dominica* died, within 16 days. No mortality was however observed in the case of *T. castaneum*.

Chander *et al.,* (2001) observed the effect of rhizomes of Sweet flag (*A. calamus*) on grubs and adults of *T. castaneum,* after an oral administration, for a prolonged period. Periodical observations over 125 days, revealed a phago-deterrent activity of the botanical tested. Park *et al.,* (2003) has tested the contact application and fumigation effect of *Acorus gramineus* rhizome extract against the adults of *S. oryzae, C. chinensis* and *Lesioderma serricorne.* The insecticidal constituents of the extract were characterized as Phenyl Pro Penes (Z)-asarone and (E)-asarone by the spectroscopic analysis. This indicated that the toxicity of asarones might be due to the *cis*-configuration rather than the position of the double bond in their molecules. It was also observed that the insecticidal activity of the compound was largely credited to its fumigation action.

Lale and Mustapha (2000) have evaluated the efficacy of four dosages (25, 50, 75 and 100 mg) of neem seed oil, applied on cowpea seeds, for reducing the reproductive potential of *C. maculatus,* in three storage devices (two unventilated and one ventilated), over a period of three month. Damaged seeds, ranged from 0.6 %, in the first month of storage, to 3.4 %, in the third month (in NSO-treated seeds) and from 8.3 %, in the first month, to 100 %, in the third month (in untreated seeds). Treatments with Neem seed oil imparted a strong objectionable flavour and aroma to the cooked cowpea seeds. Ahmed (2000) studied the efficacy of Castor-seed extract, as an insecticide, against *S. oryzae.* Which could to be inhibiting cholinesterase and peroxidase enzymes in the insect body and the enzyme-inhibition levels varied differently in adult insects, at different exposure times and with the extracts taken with different solvents.

Islam *et al.,* (2000) *Aphanamixis polystachya* locally grown in Bangladesh were evaluated for its repellent and feeding deterrent activity against adult red flour beetle, *T. casteneum*. All the plant extracts were found to be effective repellents and having feeding deterrent action against the beetle. It was observed that bishkatali leaf extracts have strong repellent and feeding deterrent effect followed by nishinda and pithraj.

The results also indicated that the water extract was more effective than acetone extract. The red flour beetle was more sensitive to the repellent than that of antifeedant action. Mulatu and Gebremedhin (2000) showed that the oils of *A. indica*, *Milletiaie ferruginea* and *Chrysanthemum cineraraefolium* were the most effective in partially or completely preventing *eg*g laying, and pulse beetles emergence from the laid *eg*gs. According to Raja *et al.* (2001) the adult *C. maculatus* were introduced into cowpea seeds which were stored in containers with volatile oils derived from *Mentha arvensis*, *M. piperata*, *M. spicata* and *Cymbopogon nardus*. The numbers of *eg*gs laid, adult mortality, adult emergence and subsequent seed damage were studied for four months. Tapondjou *et al.,* (2002) have observed that the dry ground leaf of *Chenopodium ambrosioides* inhibited F1 progeny production and adult emergence of the *C. chinensis* and *C. maculatus*.

Kim e*t al.,* (2003) have reported methanol extracts from 30 aromatic medicinal plant species and five plants essential oils were tested for their insecticidal activities against *Lasioderma serricorne* adults using direct contact application and fumigation methods. Responses varied with plant material and exposure time. Good insecticidal activity against *L. serricorne* adults was achieved with extracts of *Agastache rugosa* whole plant, *Cinnamomum cassia* bark, *Illicium verum* fruit and *Foeniculum vulgare* fruit as well as cinnamon (*C. cassia*), horseradish (*Cocholeria aroracia*) and mustard (*Brassica juncea*) oils applied at 3.5 mg/cm^2 in a filter paper diffusion method. Over 90% mortality at 3 days after treatment was achieved with an extract of *A. calamus* and *angustatus* rhizome. Cinnamon, horse radish and mustard oils at 0.7 mg/cm^2 were highly toxic to the adult beetles 1 day after treatment. In fumigation test with the beetle adults, insecticidal activity of horse radish oil, mustard oil and *Foeniculum* fruit extract was much more effective in closed cups than in open ones, indicating that the insecticidal activity of these materials was largely attributable to fumigant action. These naturally occurring plant extracts and essential oils could be useful for managing populations of *L. serricorne*.

Jilani *et al.,* (2003) have investigated that the growth-inhibition-effect of Neem-seed oil, obtained from different localities of Pakistan, upon the red flour beetle (*T. castaneum),* in the laboratory conditions and established significant reduction in progeny at a concentration of 250 ppm, in case of all the samples. Khan and Marwat (2003) have evaluated the powders made from leaves, seeds and bark of *A. indica* and *Nerium oleander* for their deterrent effects against *R. dominica* and got its repellency upto 96%. Lale and Maina (2003) have studied the influence of four carrier-solvents (acetone, ethanol, petroleum ether and hexane) on the efficacy of Neem- (*A. indica*) seed oil, applied at the rate of 0.04 ml / 33 ml of the cowpea seeds, against the cowpea-bruchid, *C. maculatus* (F.), under tropical storage conditions.

Rahman *et al.* (2003) has evaluated the botanical products, *viz.*, leaf powder and extract of Nishinda *Vitex negunda* Linn.), eucalyptus (*Eucalyptus macrorhyncha F.muell.*), Bankalmi (*Ipomoea* sp.), ash of babla wood (*Acacia arabica* Willd), oil of neem (*A. indica* A. Juss.), sesame (*Sesamum indicum*) and safflower (*Carthmus tinctorius*) against the attack of grain weevil (*Sitophilus granarius*) on wheat. This showed that the higher concentration of oil (0.25-1.0%) indicated lower infestation, less emergence of adults, less seed damage, less weight loss and a higher inhibition rate.

Zaidi Boeke *et al,* (2004) reported that the *A. indica* provided many useful compounds which could be applied to protect seeds in storages, against insect pests. They also reviewed the toxicological data from human and animal studies with the oral administration of different neem-based preparations. The non-aqueous extracts appeared to be the most toxic with an estimated safe dose (ESD) of 0.002 and 12.5 µg/kg bw/day.

Less toxic were the unprocessed seed-oil and the aqueous extracts (ESD 0.26 and 0.3 mg/kg bw/day, 2 µl/kg bw/day, respectively). Most of the pure compounds showed a relatively low toxicity (ESD of the azadirachtin is 15mg/kg bw/day). Safety assessments of various neem-derived preparations were made and compared with the ingestion of residues on food, treated with them as insecticide. They concluded that the use of neem derived insecticides should not be discouraged if applied with care. Hou *et al.,* (2004) compared two known repellents of stored-product insects, *viz*., DEET and neem with the protein-enriched pea flour, defatted protein enriched pea flour, and pea protein-extract for their efficacy, at reducing penetration and invasion by several common stored-product insects like *S. oryzae*, *T. castaneum*, *Cryptolestes ferrugineus* and *Oryzaephilus surinamensis*.

Bioactivities of candlewood, *Zanthoxylum xanthoxyloides* solvent extracts on control of *Sitophilus zeamais* and *C. maculatus* were assessed on maize and cowpea respectively. Of the four solvent extracts investigated, Methanol (MeOH) extract gave the highest yield of 75 %, and caused significant ($p<0.001$) mortalities in both insects. It also gave hundred percent protections to maize and cowpea against damage by *S. zeamais* and *C. maculatus* respectively, while causing complete inhibition of F1 progeny production and *egg* development within grains. All solvent extracts studied however, evoked strong to moderate repellent actions against both insect pests (Owusu *et al.,* 2007)

Few plant extracts were screened for their insecticidal activity against Red flour beetle, *Tribolium castaneum* and Saw toothed grain beetle, *Oryzaephilus surinamensis* at 0.5, 1.0, 2.0 and 5.0 percent concentrations. For *T. castaneum* the leaf extracts of yellow kaner was most effective (0.03075% R.T.) while Marigold leaf extract was least effective (0.00064% R.T.). Similary for *O. surinamens* is the bulb extract of garlic and flower extract of marigold showed maximum (0.03857% R.T.) and minimum (0.00214% R.T.) respectively. Rests of all others extract showed intermediate results against both the pests (Mishra Sameer *et al.,* 2006).

Arannilewa *et al.* (2006) have investigated the efficacy of petroleum ether extract of four medicinal plants; *Aristolochia ringens*, *Allium sativum, Ficus exasperata* and *Garcinia kola* on grain protectant against the maize weevil, *Sitophilus zeamais*. The mortality, rate of adult emergence, grain damage effect and weevil perforation index (WPI) were assessed. There was increase in adult mortality with days of exposure in all concentrations. *Ar. ringens* followed by *Al. sativum* were most potent both in adult mortality and adult emergence. This study reveals *Ar. ringens* to be a potent bio-insecticide for protecting maize grains from *S. zeamais* infestation and damage.

Kiruba *et al.* (2006) have noticed the proper storage of grains is essential to prevent infestation by stored product pests. A detailed survey of the stored product pest management strat*eg*ies followed by the people of Tirunelveli district of Tamil Nadu was done. The farmers have been protecting their stored products using biological and physicochemical methods.Saljoqi *et al.,* (2006) tested the ethanol extracts of six plants materials i.e. bakain drupes (*Melia azadirach*), habulas leaves (*Myrtus communis*), mint leaves (*Mentha longifolia*), bakain leaves, harmal shoots and seeds (*Pegnum harmala*) and lemon grass roots (*Cymbopogon citrates*) against rice weevil, *S. oryzae* were tested to determine their insecticidal properties. The tested materials with some variations had repellent and lethal effects against the pest as compared with the untreated check. Considering the % mortality of the insect as a main index, bakain drupes proved to be the most effective of these six plant materials that showed 61.2 % mortality, followed by habulas (48.40%), mint (47.40%) and bakain leaves (46.80%), and while harmal (16.80%) was found less effective followed by lemon grass (35.20%).

Rajapakse (2006) observed the role of plants and their usage in controlling the stored grain pests and also stated that in most of the tropical countries including Sri Lanka beetles attack store seeds which is a major cause of serious post harvest losses. In order to protect the stored product from insects not only pesticides but a formulation of plants and their products as powders, volatile oils, non volatile oils and extracts could be effectively used. Rahman and Talukder (2006) studied the bio-efficacy of the extracts, powders, ashes and oils of nishinda, (*Vitex negundo* L.), eucalyptus (*Eucalyptus globulus* Labill.), bankalmi *(Ipomoea sepiaria* K.), neem (*A. indica* L.), safflower (*Carthamus tinctorius* L.), sesame (*Sesamum indicum* L.) and of 'bablah' (*Acacia arabica* L.) against *C. maculatus* F., fed on *Vigna mungo* seeds, for the oviposition-inhibition, surface-protection, residual-toxicity and direct-toxicity. Which showed that least number of F1 adults, emerged from black gram seeds, treated with neem oils, as compared to others. The oil treatment did not show any adverse effect on the germination capacity of seeds, even after three months of the treatment.

Experiments were conducted to study the bio-efficacies of different plant/weed derivatives against *C. maculate*. The observed finding showed that plant oils were effective in checking insect infestation. The least number of F1 adults emerged from black gram seeds treated with neem oil.The nishinda oil extract was the most toxic of three extracts tested (nishinda, eucalyptus and bankalmi). Bablah ash was the most effective compared to the powdered leaves of nishinda, eucalyptus and bankalmi. The powdered leaves and extracts of nishinda, eucalyptus and bankalmi, at a 3% mixture, provided good protection for black gram seeds by reducing insect oviposition, F1 adult emergence and grain infestation rates. The oil treatment did not show adverse effects on germination capability of seeds even after three months of treatment (Rahman and Talukder, 2007).

Rajesh Kumar *et al.,* (2008) were carried out experiments to determine the potential of using essential oil from leaves of *Aegle marmelos* to control insect infestation of stored gram from *C. chinensis* and wheat from *R. dominica, S. oryzae* and *Tribolium castaneum*. After introducing the test insects, stored gram and wheat samples were fumigated with essential oil of *Aegle marmelos* at 500 µg/mL. The oil significantly enhanced feeding deterrence in insects and reduced the grain damage as well as weight loss in fumigated gram and wheat samples infested with all insects except *T. castaneum*. The essential oil at different doses significantly reduced oviposition and adult emergence of

C. chinensis in treated cowpea seeds. The oil protected stored gram from *C. chinensis* and wheat from *R. dominica* and *S. oryzae* for two years. Limonene (88 %) was found to be the major component in the oil through GC-MS analysis. The analysis of data on individuals in treated cowpea confirmed that significant reduction of oviposition and adult emergence of *C. chinensis* decreased with increase in doses. This findings emphasize the efficacy of *A. marmelos* oil as fumigant against insect infestations of stored grains and strengthen the possibility of using it as an alternative to synthetic chemicals for preserving stored grains.

Farshad Haghighian *et al.,* (2008) studied the chemical composition of worm wood *Artemisia annua* (Astraceae), a medicinal plant, by gas chromatography and gas chromatography-mass spectrometry (GC-MS). About 60 compounds were identified, from which the major compounds were erythritol, camphore, pinocarveol and diethoxyethane. The effect of crude extract on deterrency was maximal in 1000 µl/l treatment (only 4.66 insects were attracted to treated food) compared to control (12.6). The growth r*eg*ulatory effect showed that 1600 µl/l treatment variously affected the weight of larvae, pupae and adult and finally the ovicidal effect and the number of adults appearing in F1 were similarly affected and comparing to control

The susceptibility of *C. maculatus* and *D. basalis* to *Jatropha* seed oil was evaluated under laboratory conditions. The adults of *C. maculatus* and *D. basalis* had the same susceptibility to *Jatropha* seed oil but the parasitoid was relatively more susceptible than its host at all treatment levels. The oil was also have repellent to *C. maculatus* but its persistency declined from 15 to 60 days in storage. The *eg*gs of *C. maculatus* were comparatively more susceptible to the *Jatropha* seed oil than those of the parasitoid due to the protection afforded by the grain. However, the larvae and pupae of *C. maculatus* showed a relatively lower susceptibility to the oil. It is possible to incorporate the oil in a well designed pest management programme taking advantage of the short persistency of the oil on grains and its relatively ineffectiveness against the *C. maculatus* pupae developing inside the grain (Boateng and Kusi, 2008).

Asogwa *et al.,* (2009) designed a study to evaluate the protective properties of ethanol extracts of 5 plant materials against the kola weevils on stored kolanuts. The development and emergence of adult weevils were assessed by counting newly emerged adult weevils at fortnightly intervals for 112 Days. The number of weevil exit holes on the kolanuts and the number of kolanuts with color change in each treatment were also determined. The number of kolanuts with color changes recorded for the standard treatment are differed only completely from the various treatment. Generally, there was difference amongst the various extract treatments means, so none could be claimed to be superior to the other. Storage of kolanuts at 2.5x103 ppm was found adequate and recommended taking into consideration their general protective effectiveness of the kolanuts and for economic reasons.

The root of *Zanthoxylum zanthoxyloides* was screened as powder, aqueous and ethanolic extracts for toxicity to adult *C. maculatus*. Results of the acute toxicity tests showed that all the formulations were toxic to the insects. The ethanolic extract demonstrated residual property, the toxicity to *C. maculatus* remaining fairly constant over a total post-treatment time of 336 h. Cowpea grain treatment with test plant ethanolic extract resulted in reduction of the number of eggs laid from 93.30 ± 3.46 in the control to 21.00 ± 4.57 in grain treated with 0.10 g L-1 extract without significant difference in the number of adult emergence from the treated grains. Field trials showed that cowpea and maize grains treated with test plant powder were protected from insect infestation for 180 d. These results demonstrate the potentials of *Z. zanthoxyloides* for protecting cowpea and maize grains against storage insects (Denloye *et al.,* 2010)

Rahman *et al.,* (2010) conducted experiment to find out the efficacy of dodder vine extract as seed protectant against pulse beetle, *C. chinensis* on gram seed in the laboratory. Efficacies of treatments were evaluated by considering oviposition, adult emergence, intensity of damage and seed weight loss done by pulse beetle. Dodder vine extract was found effective in checking oviposition, adult progeny development and severity of seed damage. Seeds treated with 5% concentration of dodder vine extract were less preferred for oviposition, adult emergence and seed weight loss by *C. chinensis* and this concentration might be useful in protection of pulse seed.

Scientific community globally focuses their attention for searching and documenting the various activities of plants for controlling economically important agricultural pests. Petroleum ether extracts (1000 ppm) of *Vateria indica, Butea frondosa* (*B. monosperma*), *Annona squamosa, Bassia latifolia* and *Polyalthia longifolia* seeds were reported to have high antifeedant activity. The moderate activity was showedin *Sapindus trifoliatus*, *Datura alba* (*D. metel*), *Hydnocarpus wightiana* and *Semecarpus anacardium*. The positive antifeedant activity was correlated with the percentage of linoleic and oleic acid content in the seed oil (Kumar and Thakur, 1988).

Ayyangar and Rao (1989) reported that the methanol extracts of neem (*Azadirachta indica*) repelled the larvae at 0.02% concentration, as compared with 0.046% of hexane. There was no oviposition in an area treated with the methanol extract at 0.01% for 5 days as compared with 4 days for the hexane extract. More *et al.,* (1989a) stated that the aqueous and alcohol extracts of *Euphorbia* sp. and *Ipomoeacarnea* showed most effective antifeedant activity against the larvae of *S. litura*.

Luthria *et al.,* (1989) has isolated coumarin derivatives such as (Xanthyletin, Racemosin, Luvangetin, Xanthotoxin (Methoxsalen), Umbelliferone, Rutaretin and Rutarin), from the n-hexane and methanol extracts of aerial parts of *Atalantia racemosa.* Among them Methoxsalen showed the highest antifeedant activity (EC_{50} = 31 ppm.) and luvangetin moderately active (EC_{50} = 220 ppm). The linearly fused furan ring with alkoxy groups at positions 9 and 4 are important for the antifeedant activity of methoxsalen.Murthy *et al.,* (1989) studied the relative effectiveness of 7 neem fractions against 3rd instar larvae of *S. litura* in the laboratory and compared with 2% neem seed kernel suspension. The fractions 4 of 7 were showed as effective as the 2% suspension in protecting the leaves from larval damage. Clerodane diterpenoids from the labiate plant *Teucrium* showed antifeedant activity on *S. littoralis* and

Heliothis armigera (Simmonds *et al.,* 1989). Ayyangar and Rao (1992) have reported that the injection of neem extract at 1 µg/g body weight to 6^{th} instar larvae of *S. litura* will reduce the fecundity, hatchability, pupation and adult emergence.

Two new bark components, scopoletin and 7-O-(beta-D-apiofuranosyl, beta-D-glucopyranosyl)-6-methyl coumarin (xeroboside or hymexelsin) were isolated from *Xeromphis uliginosa* (*Catunaregam uliginosa*) the latter coumarin showed insect antifeedant activity against 4^{th} instar larvae of *S. litura* (Nagaiah *et al.,* 1992). The occurrence of rugosal A in the exudate of *R.rugosa* leaves suggests a possible defensive role of the glandular trichome against pest organisms, as the compound showed antifeedant activity (Hashidoko *et al.,* 1992). Hintalwar *et al.,* (1992) reported that petroleum extract of *Psoralea corylifolia* roots at 5000 ppm caused feeding inhibition on 4^{th}instar larvae of *S. litura*. The active principles Furanocoumarins, psoralen and isopsoralen were responsible for that activity. Kole *et al.,* (1992) isolated Amorphone (6-hydroxy-6a, 12a-dehydro rotenone) from the petroleum ether extract of leguminous plant *Tephrosia candida* was the most active against *S.litura* (LD_{50} 0.38 µg/g body weight). Pure compounds was also tested, rotenone, amorpholone and rotenonone had the LD_{50} s of 0.16, 0.31 and

0.68 µg/g, respectively. Russell and Lane (1993) screened eighteen plants from the New Zealand flora with low insect associations for antifeedant activity against larvae of *Planotor trixocto*, *Tenopseustis obliquana*, and *S.litura*and *Technomyr mexalbipes*. Among the plants screened *Macropiper excelsum*, *Sophora microphylla*, *Coryocarpus laevigatus*, *Dysoxylum spectabile* and *Podocarpus nivalis* had antifeedant activity for at least three insect species.

The furochromones with alkoxy substituents at C-4 or C-9 exhibited maximum feeding deterrent activity against larvae of *S. litura*. Loss of activity was noticed with the degradation or saturation of heterocyclic rings. Substitution of C-7 methyl of the gamma-pyrone ring and dealkylation of C-4 or C-9 methoxyl also caused considerable reduction in feeding deterrent (Luthria *et al.*, 1993). Isman (1993) was reported that azadirachtin added to an artificial diet inhibited neonate larval growth in a dose-dependent fashion in *Actebiafennica* (*Ochropleura fennica*), *Mamestra configurata, Melanchra picta, Peridroma saucia*, *S. litura* and *Trichoplusia ni*. The EC_{50} following 10 days of feeding ranged from 0.12 to 0.24 mg/kg, but without significant differences between species. However, when 2nd instar larvae were offered a choice, only larvae of *P. saucia* and *S. litura* discriminated between an untreated diet. A more sensitive behavioural bioassay using 4th instar larvae indicated that *S. litura* was the most sensitive to the antifeedant (EC_{50} 1.25 mg/cm^2) and *A. fennica* was the least (40.7 mg/cm^2). Topical treatment of 4th - instar larvae with 50 or 100mg azadirachtin resulted in a significant inhibition of subsequent growth, diet consumption and dietary utilization.

Chari *et al.,* (1993) studied the bioefficacy of some neem extract formulations (0.0018% Margosan-O, 0.1% neem rich II, 0.75% F6, 1% repelin, 2% Wellgro, 0.01% Neemark, 1% dichloroethane extract, 1% alcohol extract, 2% neem oil emulsion and 2% neem seed kernel suspension) against *S. litura*. Repelin, dichloroethane extract and neem seed kernel suspension gave the best protection in laboratory tests. Biosol, Neemark, Repelin and neem oil were tested at 0.5-3.0% against larvae of *S. litura* in the laboratory. Repellency, antifeedant activity and development period increased with increase in concentration of all pesticides. Adult emergence, growth, survival, larval and pupal weight, number of eggs laid and hatchability of eggs decreased with increase in concentration. Neem oil had the greatest effects, followed by Neemark, Biosol and Repelin (Rao *et al.,* 1993). Neem leaf and seed extracts and

Pongamia glabra P. pinnata)seed extracts were highly effective giving 75.5, 88.96 and 66.4% protection, respectively at 15% concentration (Koshiya and Ghelani, 1993).

Murthy *et al.,* (1993) tested Neem extracts against *S. litura* on tobacco in the laboratory and nursery. Dichloroethane extract was more effective than neem. Dichloroethane extract of neem and neem cake could prevent damage by *S. litura* on tobacco nursery. Effects of azadirachtin-rich fractions on larvae of *S. litura* revealed that it has strong antifeedant properties. Larval mortality due to malformation was observed in Vemidin, Nem-75 and Nemidin, and adult malformation was noticed in Nemidin treatments (Jeyarajan *et al.,* 1993). Lajide *et al.,* 1993 reported that the crude methanolic extract of roots of *Aristolochia albida*. Experiments with derivatives of the extracts suggested that a free carboxylic acid group in close proximity to a nitro group in the aristolochic acid ring structure is important for antifeedant activity.Kweon *et al.,* (1994) reported that the methanol extracts from 30 species of oriental medicinal plants belonging to 24 families were tested for their larvicidal and antifeedant activities against *Plutella xylostella* and *S. litura* by a leaf-dipping method at a concentration of 5000 ppm. Strong antifeedant activity was observed against *P. xylostella* in

Platycodon grandiflorus, Codonopsis pilosula, Asarum sieboldii, Rhus chinensis and *Lithospermum erythrorhizon* extracts. Antifeedant activity against *S. litura* was observed in *Akebia quinata* and *Equisetum hyemale*. Antifeedant activity against both insects was obtained from *R. chinensis* and *Copti chinensis* extracts.

Govindachari *et al.,* (1994) explained the structure-related antifeedant activity of azadirachtin A, B, D, H and I against *S. litura* using both no-choice and dual choice bioassays. The importance of the type of substitutions in the decalin rings A and B of the azadirachtin molecule was enhancing the antifeedancy. Gonzalez-Coloma *et al.,* (1994a&b) studied the extracts of *Apollonia barbusana, Laurus azorica, Persea indica* and *Ocotea foetens* and *Reticulitermes speratus* for their contact toxicity against *Drosophila melanogaster* and for their larvicidal activity against the mosquito *Aedes aegypti*. Extracts of *P. indica* had a strong antifeedant effect against *S. litura.*

Mohapatra *et al.,* (1995) reported that different solvent extracts of neem cake kernels were evaluated against *S. litura* on cauliflower (*Brassica oleracea* var. *botrytis*) leaves. Aqueous extract was dissolved in ethanol and methanol extract in ethanol and dissolved parts were designated as fraction I and fraction II, respectively. Among the solvent extracts tested at 1.0 % concentration, methanol extract provided the greatest protection (100%) of the leaves followed by ethanol (98.39%) and aqueous (93.01%) extracts. Fraction I and II were equally effective at 0.1% concentration against S. *litura* larvae and prevented more than 70% of leaf damage. However, such extracts were found to be unstable when exposed to sunlight. The pre-gelatinized starch-encapsulated products, pre-gel I and pre-gel II were quite stable and afforded more than 68.0% protection to the cauliflower leaves even after 6 days of exposure to sunlight.

Durairaj and Venugopal (1995) reported that Neem oil 2% + diflubenzuron 0.015% had the greatest antifeedant effect (leaf area consumed = 9.3 cm^2) and produced early larval mortality in *S. litura*. In *H. armigera*, the greatest antifeedant effect and early larval mortality was recorded 13 days after treatment with neem oil 2% + diflubenzuron 0.03%. Larval mortality was due to a difficulty in moulting between various instars and the formation of larval-pupal intermediates.Naumann and Isman (1995) reported that 1% crude oil emulsion significantly reduced the proportion of eggs laid by *S. litura* on treated plants. It is suggested that literature reports of significant neem-based oviposition deterrence to *S. litura* are the result of compounds that are removed by higher levels of processing and thus not likely to be found in most commercial neem seed formulations. Opender Koul *et al.,* (1995) studied the petioles of intact castor leaves (*Ricinus communis*) were placed in emulsified solutions of azadirachtin (isolated from neem seeds) for 24h and systemic translocation was observed. Performance of 1st - instar larvae of *S. litura* provided with such treated leaves was affected. Similar effects were seen in 3rd and 4th instar larvae, when treatment was systemic through soil drench method. Cessation of feeding and lack of larval weight/ gain were observed with concomitant moult inhibitions at concentrations ranging from 5 to 20 ppm. Effective intensity treatment of azadirachtin solutions applied directly as a spray to the surface of castor seedlings was not of the same order as required for systemic treatment which showed more persistence compared with the simple foliage sprays.

Sahayaraj and Sekar (1996) reported that the leaves of *Azadirachta indica, Vitex negundo*, rind of *Citrus sinensis* (orange) and rhizome of *Zingiber officinale* (ginger), 10 g of each were macerated in hot distilled water and applied to groundnut leaves to assess their efficacy against larvae of *S. litura*. Larval mortality was highest after 96 hrs on leaves treated with orange (90%), followed by *V. negundo* (83%), *A. indica* (80%) and ginger (70%). Aqueous extracts of *Annona reticulata,* *Datura innoxia* (*D. fastuosa*), *Calophyllum inophyllum, Pongamia glabra* (*P. pinnata*), *Calotropis gigantea*, *A.indica* (neem) and *Thevetia peruviana* and the rhizome of *Acorus calamus* were tested for their activity against 4th instar larvae of *S. litura*. Neem seed kernel extract was the most effective, causing 100% mortality 10 days after treatment (Behera and Satapathy, 1996).

Govindachari *et al.,* (1996) studied the antifeedant and insect growth-regulating activities of salannin, nimbin, and 6-deacetylnimbin, in comparison with azadirachtin-A, against *S. litura, Pericallia ricini* and *Oxya fuscovittata*. Salannin deterred feeding, delayed moulting by increasing larval duration, caused larval and pupal mortalities, and decreased pupal weights into the two Lepidoptera. Salannin also caused moult delays and nymphal mortalities in *O. fuscovittata*. Lee and Shih (1996) reported that the comparative effectiveness of an insecticidal substance extracted from seeds of *Melia azedarach* against 2nd instar larvae of *S. litura. Teucrium haenseleri* exhibits antifeedant activity against larvae of *S. littoralis* and *Heliothis armigera.* 20-Deacetyleriocephalin was isolated from aerial parts of *T. haenseleri* (Gaspar *et al.,* 1996). Shukla *et al.,* (1996) reported that Ursolic acid isolated from leaves and stems of *D. myoporoides* was a potent antifeedant and produced 90.12 and 91.96% inhibition at 5000 ppm against *S. obliqua* and *S. litura*, respectively. Bergenin was isolated from the rhizomes of *A. rivularis* and used as an antifeedant bioassay by faecal pellet counting method against *Spilosoma obliqua* (*Spilarctia obliqua)* and *S. litura*. Bergenin exhibited significant antifeedant activity with ED_{50} values of 2432 and 2187 ppm for *S. obliqua* and *S. litura* (Mamta *et al.,* 1996). Dewaxed leaf surface extracts of 12 plants from Hokkaido, prepared by dipping fresh leaves in chloroform for 3 minutes, were used in a choice leaf-disc bioassay against larvae of *S. litura*. Activity was found only in an extract from *Senecio cannabifolius*, a very successful weed in Hokkaido. However, individual fractions of the extract were not active. Incorporation of individual fractions of the surface extracts as well as fractions of the methanolic extracts of the leaf residue into an artificial diet fed to neonate larvae of *S. litura* led to the isolation of ethyl acetate (1-hydroxy-4-oxocyclohexa-2, 5-dien-1-yl) the major surface compound, as the active principle. This compound was also present in the methanolic extract of the leaf residue together with methyl acetate (1-hydroxy-4-oxocyclohexa-2, 5-dien-1-yl) that had the same growth inhibitory effect on larvae. The presence of these compounds in the foliar surface and tissue suggests a defensive role against herbivores (Lajide, *et al.,* 1996).

Gonzalez-Coloma *et al.* (1996) have studied the ryanodane diterpenes cinnzeylanone, ryanodol 14-monoacetate and epi-cinnzeylanol which was isolated from *Persea indica*. Cinnzeylanol and ryanodol were the most active antifeedants of this plant with a range of activity close to that of ryanodine. Shukla *et al.,* (1997) reported that Oleanolic acid isolated from the sapogenin fraction of roots of *P. quinquefolium* (*P. quinquefolius*) was bioassayed by leaf disc method for feeding-deterrence in *S. obliqua* and *S. litura*. Oleanolic acid (3000 ppm) displayed 98.75 and 97.26% feeding-deterrence against *S. obliqua* and *S. litura,* respectively.

The non-toxic vegetable oils, karanj (*Pongamia pinnata*) oil, neem. (*A. indica*) oil, citronella oil, and piperonyl butoxide (PBO) were separately used in mixed formulations with cypermethrin at various ratios (1:1, 1:2, 1:5, 1:10) and evaluated against 1-, 4-, 7- and 9-day old larvae of *S. litura* by leaf dip and direct spray methods. With the change in age of *S. litura* larvae, the method of application was evident on the synergistic activity of different vegetable oils. When the leaf dip method was used, karanj oil synergised cypermethrin against 4, 7 and 9 day old larvae. But with PBO, the synergistic activity was obtained only on 7 and 9 day old larvae. With the direct spray method, the synergistic activity of neem oil in the formulation was pronounced against 4 and 9 day old larvae and also, karanj oil exhibited synergism against 1, 7 and 9 day old larvae. However, citronella oil showed synergistic activity only on 7-day old larvae. Evidently karanj oil, the type of action changed from additive to synergistic as the age of the larvae increased from 1 to 9 days (Rao and Dhingra, 1997).

Datta and Saxena (1997) reported that Azadirachtin-A was considerably more effective than parthenin as an antifeedant in dual-choice tests. Three new diterpenes with the rare isoryanodane skeleton, indicol, vignaticol and perseanol, were isolated from aerial parts of *P. indica* (collected from Tenerife, Canary Islands). These compounds proved to be antifeedants against *S. litura*, perseanol being the most active. (Fraga *et al.,* 1997). Significant increases in larval mortality, antifeedant and ovipositional repellency was found in reddish terminal leaves exudate of *Azadirachta indica* (Kumar *et al.,* 1997). The antifeedant activity of diisoflavones was tested employing the non-choice test method against 4th-instar pre-starved larvae of *S. litura* and the results showed antifeedant activity (Murthy *et al.,* 1997).

Li-Xiao Dong *et al.,* (1998) studied the insecticidal components of leaf extracts of *Aglaia odorata var. chaudocensis* and their toxicity to *S. litura*. Insecticidal activity of methanol extract was higher than chloroform and petroleum extracts. The methanol extract was partitioned by chloroform, and column chromatography of chloroform partitioning on neutral alumina gave 5 fractions, in which fraction 4 was more active than the others. The medium antifeedant concentration (AFC_{50}) of fraction 4 against 4^{th} - instar larvae was 0.12%, the LC_{50} was 0.13%, and the EC_{50} (concentration inhibiting growth by 50% relative to control) was 0.21%.Yasui *et al.,* (1998) reported that momordicine II, a triterpene monoglucoside, isolated from the methanol extract of *M. charantia* leaves inhibited feeding of the armyworm. The second active fraction led to the isolation of a new triterpene diglucoside. Momordicine II showed significant antifeedant effects on *P. separata* at 0.02, 0.1, and 0.5% concentrations in artificial diets. Momordicine II caused a significant feeding reduction in *S. litura* only at the highest concentration (0.5%). Sahayaraj (1998) studied the plant extracts of *A. indica* (neem), *Citrus sinensis* (oranges), *Vitex negundo* and *Zingiber officinale* (ginger) against last instar larvae of *S. litura.* The strongest deterrent effect was found in *V. negundo* and was indicated by very low food consumption and digestibility, faecal pellets production and reduced body weight. The percentage of deformity in pupal as well as adult stages was highest in *Z. officinale* followed by *A. indica* and *C. sinensis.*

A methanolic neem seed extract inhibited feeding at a concentration of 0.3% and the feeding was further reduced at 0.5% of neem extract was fed to larvae of *S.litura* (Kulkarni, 1999). Parvathi *et al.,* (1999) reported that toxicity, antifeedant, and growth-regulatory activity of methanol extracts of *Gliricidia sepium* against *Dysdercus koenigii*, *Achaea janata* and *S. litura*. Topical application of 100 - 300 µg of the of methanol extracts of *Gliricidia sepium* leaves extract to different stages of the test insects resulted in concentration-dependent effects including larval-pupal intermediates and deformed adults. The highest tested concentration (300 µg / µl) resulted in a reduced survival rate and morphological abnormalities.

Chari *et al.,* (1999) reported that Neem Azal FI and II at 50 ppm concentration, NSKE 2% and chlorpyrifos 0.05% gave significant protection to tobacco seedlings from the *S. litura* damage followed by Neem Azal F II (25 ppm) and Neem Azal F I (30 ppm). Fortune Azal at 50 ppm gave equal protection as chlorpyrifos 0.05% and NSKE (neem seed kernel extracts) 2% up to nine days after spraying. All the neem extracts were significantly more effective against *S. litura* on tobacco than *Pongamia* treatments. Neem oil at 1.5% concentration was found highly effective and on par with 2% NSKE, chlorpyrifos and CTRI-III neem extract. *Pongamia* CTRI-III (*Pongamia* oil 1.5%) and alcoholic extract of neem without oil (CTRI-IV) at 50 ppm were the next best treatments. Opender Koul *et al.,* (2000) reported that dichloroethane (DCE) and methanol extracts of *M. dubia* inhibited growth of *S. litura* and *H. armigera* by artificial diet bioassays method. DCE and Me-5II fractions also resulted in 50% deterrency at concentrations of 22.5 and 16.8 µg/cm^2, respectively against *S. litura* larvae in a leaf disc-choice test. The DCE-5 fraction was more toxic to larvae (LC_{50} of 0.65%) than the Me-5II (LC_{50} of 0.8%), 72h after topical application. Although salanin was isolated from the DCE fraction showed antifeedant activity.

Chen *et al.,* (2000) explained that the insecticidal activity of methanol, acetone, ethyl acetate, chloroform, benzene and petroleum ether extracts of *Daphne tangutica*. The crude extracts of the five former solvents were proved to possess strong antifeedant effects when applied to 3rd instar larvae of the tobacco cutworm, *S. litura*, during preliminary bioassays. Sahayaraj and Paulraj (2000) reported that crude leaf extract of *Tridax procumbens* was shown to have a repellent effect on 4th instar larvae of *S. litura*, repellency increasing with 0.5, 1, 2, 4 and 6% concentration. Pupae and adults developing from treated pupae showed deformities.

Antifeedant activities of *Artemisia nilagrica* and *Juglans regia* var. *kumaonica* (*Juglans regia var. kamaonia*) leaf oils against *Spilosoma obliqua* (*Spilarctia obliqua*) and *S. litura* larvae were observed to be dose dependent for both insects. *A. nilagrica* oils showed greater feeding deterrence than *J. regia var. kumaonica* oils. Considerable feeding inhibition (80.21% and 70.21%) was recorded for 3rd instar larvae of *S. obliqua* treated with 0.4% concentrations of *A. nilagrica* (EC_{50}=0.080%) and *J. regia var. kumaonica* (EC_{50}=0.150%) oils, respectively, while 0.3% extracts of *A. nilagrica* (EC_{50}=0.042%) and *J. regia var. kumaonica* (EC_{50}=0.10%) registered feeding deterrence when tested on 5th instar larvae of *S. litura* by 83.76% and 63.12%, respectively (Chowdhury *et al.,* 2000).

Morimoto *et al.,* (2000) reported antifeedant activity of flavonoids and 4, 4', 6'-trihydroxy-2'-methoxy-chalcone isolated from cudweed, *Gnaphalium affine*. Four natural flavonoids showed insect antifeedant activity against *S. litura*. Therefore, these natural compounds were regarded as one of the plant's defensive systems against phytophagous insects along with the woolly plant surface.Studies conducted on the effects of volatile oil constituents of *Mentha* species are highly effective against *C. maculatus* and *T. castanum*, the common stored grain pests

(Tripathi *et al.,* 2000). A number of source plants have been traditionally used for protection of stored commodities, especially in the Mediterranean region and in Southern Asia, but interest in the oils was renewed with emerging demonstration of their fumigant and contact insecticidal activities to a wide range of pests in the 1990s (Isman, 2000).

The larvae of *T. castaneum* were tolerant to diallyl trisulphide from the essential oil of *A. sativum* safrole from the essential oil of *Sassafras albidum* and isosafrole from the oil of *Canangium odoratum* (Huang *et al.,* 1999, Chiam *et al.,* 1999; Huang *et al.,* 2000). Three groups of entomotoxic peptides (8000– 12,000 Mr. Range) were separated by gel-filtration. When canatoxin's toxic peptides were fed to the insects simultaneously with cathepsin inhibitors, no protective effect was seen. These results confirmed the proteolytic activation of canatoxin by insect cathepsin-like enzymes to produce entomotoxic peptide (s) (Carlini *et al.,* 2000).

Recent experiments were conducted on larval tissues to understand why arcelin is an insecticidal factor for *Z. subfasciatus* but not for *A. obtectus*. These studies showed that arcelin-1 disrupted the epithelial structure in some regions on the midgut of *Z. subfasciatus* but not in the midgut of *A. obtectus* larvae (Paes *et al.,* 2000). Essential oils of *Ocimum* *sanctum* caused 20% mortality to 3rd instar larvae of *S. litura*. At a topical dose of 100 µg/larvae, > 90% larval mortality has been reported when essential oil of *Satoreja hortensis*, *Thymus serpyllum* and *Origanum creticum* (LD_{50} = 48.4–53.4) were applied to 3rd instars *S. litura* (Isman *et al.,* 2001). Carvone was similarly effective as adulticide while menthol was most effective as fumigant against *T. castaneum* and *C. maculatus.* 1,8-cineole on the other hand exhibits both contact and fumigant toxicity when tested against *T. castaneum* (Tripathi *et al.,* 2001). During evolution, pests have been in contact with a variety of proteinase inhibitors produced naturally by their host and they have consequently, developed strategies to deal with their inhibitory effects. The adaptation of insect pest to plants over-expressing proteinase inhibitors was clearly demonstrated, but it is not clear yet how the presence of the proteinaceous inhibitors in the intestinal tract leads to the induction of insensitive digestive proteinases (Bolter and Jongsma, 1995; Brito *et al.,* 2001; Paulillo *et al.,* 2000; Powell, 2001).

Essential oils or their components showing fumigant action generally have low mammalian toxicity. For example, the oral LD_{50} values (mg/kg body weight) for rats for some of the essential oils are *A. calamus* oil (0.78), caraway oil (3.50), eucalyptus oil (4.44), thyme oil

(2.84) and peppermint oil (4.41) and that of the constituents are anethole (2.09), carvacrol (0.81), 1,8-cineole (2.48),cymene (4.75), limonene (4.60), linalool (2.79) and terpineol (4.3). At the same time, it must be noted that all compounds found in plant essential oils are safe. Estragole and fenchone in the essential oil of *M. vulgare* (which are highly effective against *S. oryzae*, *C. chinensis* and *L. serricorne* adults) are known to be carcinogenic (Kim and Ahn, 2001).Limonene found in the essential oil of various citrus leaves and fruit peels have exhibited significant insect control properties. Menthone, *trans*-anethole and cinnamaldehyde are well known anti-insect compounds that have been studied against variety of insects with wide range of dosage required to kill 50% population (Chang and Cheng, 2002).However, plants whose essential oils have been reported to have repellent activity include citronella, cedar, verbena, pennyroyal, geranium, lavender, pine, cinnamon, rosemary, basil, thyme, and peppermint. Most of these essential oils provided short-lasting protection usually lasting less than 2 h. Many essential oils and their monoterpenic constituents are known for their mosquito repellent activity against *Culex* species (Choi *et al.,* 2002; Traboulsi *et al.,* 2002).

Cimanga *et al.,* (2002) demonstrated the antibacterial activity of essential oil extracted from *Eucalyptus camaldulensis*, *E. tereticornis, E. alba, E. citriodora, E. deglupta, E. globulus, E. saligna,* and *E. robusta* against *Pseudomonas aeruginosa*. They concluded that composite essential oils were more effective than the additive activity of their major constituents such as 1,8-cineole, a-pinene, and p-cymene. Eucalytpus species not only provide fuel biomass and reduce atmospheric carbon dioxide levels directly, but also perform a variety of indirect services through their essential oil used as insect/pest repellent and as a pesticidal agent (Barton *et al.,* 2000; Martin, 2002). Essential oils derived from eucalyptus and lemongrass have also been found effective as animal repellents, antifeedants, insecticides, miticides and antimicrobial products; thus finding use as disinfectants, sanitizers, bacteriostats, microbiocides, fungicides and some have made impact in protecting household belongings. The larvicidal activity of citronella oil has been mainly attributed to its major monoterpenic constituent citronellal (Zaridah *et al.,* 2003). The rapid action against some pests is indicative of a neurotoxic mode of action, and there is evidence for interference with the neuromodulator octopamine (Kostyukovsky *et al.,* 2002a) by some oils and with GABA-gated chloride channels by others (Priestley *et al.,* 2003).

Tripathi *et al.,* (2003) has reported toxicity of essential oil of *Aegle marmelos* by topical application to *S. litura* larvae with LD_{50} of 116.3 µg/larvae. Monoterpenes being volatile are more useful as insect fumigants. Several studies have been undertaken in the past to explore the potential of oils and their constituents as insect fumigants. Products isolated/derived from *Curcuma longa* (turmeric) and *Zingiber officinale* (ginger) have also been found effective as insect antifeedant and insect growth regulators (Agarwal and Walia, 2003).

There are several examples of essential oils like that of rose (*Rosa damascene*), patchouli (*Pogostemon patchouli*), sandalwood (*Santalum album)*, lavender (*Lavendula officinalis*), geranium (*Pelargonium graveolens*), etc. that are well known for their pest control properties. While peppermint (*Mentha piperita*) repels ants, flies, lice and moths; pennyroyal (*Mentha pulegium*) wards off fleas, ants, lice, mosquitoes, ticks and moths. Spearmint (*Mentha spicata*) and basil (*Ocimum basilicum*) are also effective in warding off flies. In fact, effects on natural enemies have yet to be evaluated under field conditions (Kostyukovsky *et al.,* 2002a; Bischof and Enan, 2004). Hierro *et al.,* (2004) has reported the action of different monoterpenic compounds against *Anisakis simplex* larvae and found that geraniol, citronellol, citral, carvacrol and cuminaldehyde were active at 12.5 μg/ml concentrations.

Cinnamaldehyde, eugenol, cinnamyl acetate and essential oils from different *Cinnamomum* species are effective mosquito larvicides similarly; natural essential oils have shown a high attractiveness for greenhouse whitefly, *Trialeurodes vaporariorum* (Gorski, 2004). Among the various components of eucalyptus oil, 1,8-cineole is the most important one and in fact, a characteristic compound of the genus Eucalyptus, and is largely responsible for a variety of its pesticidal properties (Duke, 2004).The toxicity of essential oils/components in combination with atmospheric gases and ethylformate fumigant has been investigated. In studies on the joint action of ethyl formate with different monoterpenes, Waterford *et al.,* (2004) observed enhanced toxicity of the (95:5% v/v) mixture containing carvone or thujone against the pupae of *S. oryzae* in a 24 h exposure at 25 1C. CO_2, a respiratory stimulant is a known adjuvant for fumigants including phosphine and methyl bromide. Eggs of *A. obtectus* that was less tolerant to the essential oils of *L. hybrida, R. officinalis* and *E. globulus* (Papachristos *et al,* 2004). Trivedi and Hotchandani (2004) showed that strains of *Klebsiella* spp., *Proteus* spp., *Pseudomonas* spp., *Escherichia coli* and *Staphylococcus aureus* resistant to conventional antimicrobials were inhibited by the commercially available eucalyptus oil containing 63% 1,8-cineole. Omolo *et al.,* (2004) evaluated the repellent activities of geraniol, citronellal, perillaldehyde, caryophyllene moxide, carvacrol, 4-isopropyl-benzenemethanol, thymol, 3-carene and myrcene. Tests have also been carried out with pure compounds obtained from commercial sources or synthesized in the laboratory (Peterson *et al.,* 2000; Park *et al.,* 2004).

The essential oil bearing plants like *Artemesia vulgaris*, *Melaleuca leucadendron*, *Pelargonium roseum*, *Lavandula angustifolia*, *Mentha piperita*, and *Juniperus virginiana* are also effective against various insects and fungal pathogens (Kordali *et al.,* 2005). Turmeric plant oil is also very useful in pest control. The turmeric leaves and unutilized parts of turmeric plant, on hydrodistillation yields oil rich in 2-phellandrene (70%) that inhibits growth of *S. obliqua* and diamond back moth, *Plutella xylostella* (Linnaeus) at 1.0 % concentration (Govindaraddi, 2005; Walia, 2005).

The mosquito repellent activity of 38 essential oils was screened against the mosquito *A. aegypti* under laboratory conditions using human subjects (Trongtokit *et al.,* 2005). The fruit oil of *Piper retrofractum* has also shown high repellency (52–90%) against *T. castaneum* at 0.5–2% concentration (Chahal *et al.,* 2005). Garlic oil which is also an oviposition deterrent has been found to be highly toxic to eggs of *P. xylostella* and 99.5% reduction in egg hatching has been recorded in *S. obliqua* at 250 mg oil/50 eggs using essential oil of *Aegle marmelos* (Govindaraddi, 2005). The essential oil and a number of extracts of *Rosmarinus officinalis* L. in solvents of increasing polarity have been isolated, and their components identified and tested as pest control agents. Ethanol and acetone extracts attract grape berry moth, *Lobesia botrana*. However, none of the extracts had a significant effect on western flower thrips, *Frankliniella occidentalis* (Katerinopoulos *et al.,* 2005). The other oils also showed inhibitory activity against other viruses (Rao *et al.,* 2005).

The metabolites isolated from *Baccharis salicifolia*, and some derivatives prepared from germacrone and pulegone were evaluated against *T.castaneum.* However, perhydrogermacrone, dihydropulegone (germacrone and pulegone hydrogenation derivatives), b-pinene and germacrene did not show any activity. This suggests that the hydroxyl group positively affects the repellent activity against *T. castaneum* (Garcia *et al.,* 2005). Yang and Ma (2005) reported that protection time has been increased against *A. albopictus* of a 15% alcoholic solution of *Eucalyptus globulus*, by adding a 5% of vanillin. Of late, CDC (Center for Disease Control and Prevention, USA) recommended the use of lemon eucalyptus oil (with p-menthane-3,8-diol, PMD, as active ingredient) for protection against West Nile virus that causes neurological disease or even death and is spread by mosquitoes (Kuehn, 2005).

Meepagala *et al.,* (2006) found that apiol isolated from *Ligusticum hultenii* exhibited high termiticidal activity of 100% within 11 days after treatment and similar effect was shown by vulgarone B isolated from

Artemisia douglasiana, where as cnicin isolated from *Centaurea maculosa* showed mortality of 81% within 15 days after treatment when applied at 1.0% (w/w) concentration to these termites. Citral (3,7-dimethyl 2,6-octadienal), the most important member of acyclic monoterpenoids is a liquid which has smell of lemon and occurs to an extent of 60– 80% in lemon grass oil. Due to the presence of *E* (*trans*) and *Z* (*cis*) geometric isomers. Essential oils rich in 1, 8-cineole are also effective against house dust mites (Miresmailli *et al.,* 2006). These studies indicate that such compounds can make substantial impact as commercial products, if suitable delivery systems are developed.

The ability of these natural products to kill arthropods at relatively low concentrations also represents an alternative to the use of synthetic pesticides for control of disease vectors (Panella *et al.,* 2005; Dietrich *et al.,* 2006). The mechanism of action of oil compounds against fungi is unknown but may be related to their general ability to dissolve or otherwise disrupt the integrity of cell walls and membranes (Isman, 2006). It is thus pertinent to explore the pesticidal activity of natural products (Oerke, 2006).The toxicity may be by contact, ingestion or through fumigant action. Focus on the vapour or fumigant toxicity of essential oils of plants and their constituents has sharpened since the

1980s. There are many reviews dealing with the use of plant products in general, against insect pests of stored products specifically on essential oils and others only on monoterpenoids (Isman, 2006; Saura-Calixto and Goni, 2006).

According to Koul *et al.,* (2007), orange oil extracted from citrus peel (containing ~92% limonene) caused 68% mortality to Formosan subterranean termite, *Coptotermes formosanus within* 5 days and there was significant reduction in feeding as compared to controls at 5ppm concentration (v/v), also the termites did not tunnel through glass tubes fitted with sand treated with 0.2–0.4% orange oil extract. One of the plausible explanations for such an effect could be the interference during the sclerotization immediately after the emergence from pupae, which ultimately leads to the death of beetles within 12 h of their emergence. Antifungal activities of certain essential oils or their components have also been assessed and found effective for *Alternaria padwickii*, *Bipolaris oryzae*, and peanut fungi (Nguefack *et al.,* 2007; Krishna Kishore *et al*, 2007). The essential oil of *Piper nigrum* (L.) was evaluated for its repellent, insecticidal and developmental inhibitory activities against an important wheat grain pest *Tribolium castaneum* (Ravi Kant Upadhyay and Gayatri Jaiswal, 2007).

Various known monoterpenoids have been used as binary mixtures and tested for synergy, using toxicity and feeding inhibition parameters. The data suggests that thymol and *trans*-anethole synergized the effects of linalool (at 18 µg/larva dose, combined in 1:1 ratio) but thymol with 1,8-cineole exhibited only additive effect and so was the case with terpineol and linalool combination. A definite synergism was also observed in case of isolated compounds from two different plant species, *i.e.* linalool with 1,8- cineole (Singh *et al.,* 2008).Antifeedant activities of seven chemicals isolated from *Ajuga nipponensis* were examined in a bioassay against 3rd instar larvae of *Plutella xylostella*. Five compounds (luteolin, stigmasterol, acacetin, 20-hydroxyecdysone and fraction 1) showed significant antifeedant activities against diamondback moth, with a high mortality percentage and low consumed leaf area when mixed with avermectins (Zhen huang *et al.,* 2008).A preliminary study was conducted to test 16 crude extracts of selected plants on the mortality of *Sitophilus zeamais* adult. Crude extracts of *J. curcas* seed and leaves, *A. muricata* (seed) and *A. indica* (seed) seem to have potential as botanical insecticides but further studies need to be conducted against *S. zeamais* (Asmanizar *et al.*,2008).

Aphidicidal activity of some indigenous plantswere tested against the bean aphid, *Aphis craccivora*. Hot water extract of *P. hydropiper* and *A. indica* was found to be the most effective (87.6–94.5 and 80.47–89.6% mortality respectively, $P < 0.01$) among all the extracts (Das, *et al.,* 2008).

The essential oils (EO) of *Lippia turbinate* and *Lippia polystachya* have shown lethal effects against mosquito larvae. Larvae were individually placed in glass boxes, and their activity recorded at 0.3 s intervals during 40 min. Individuals treated with doses >40 ppm of either EO significantly decreased their ambulation speed and the percentage of total time ambulating compared to controls. Their findings are consistent with the neurotoxic effect against insects attributed to α-Thujone, a main component of both EO. Both sublethal and lethal doses of TUR and POL increased the complexity of ambulation. Interestingly for POL 20 ppm, an increase in complexity was observed while no changes in general activity were detected, suggesting that fractal analysis may bemore sensitive to detect behavioral changes than general activity evaluation (Jackelyn *et al.,*2009).Essential oil of seeds of *Trachyspermum ammi* and its pure constituent thymol showed promising results when evaluated for larvicidal, oviposition deterrent, vapor toxicity and repellent activity against malarial vector, *Anopheles stephensi*. Thymol provided complete repellency toward *A. stephensi* adults at the dose of 25.0 mg/mat after 1 h duration, whereas same degree of repellency was obtained by the oil at the dose of 55.0 mg/mat, indicating its double-fold activity than the oil (Shikha and Tripathi 2009).Eggs, larvae and adults of *Tribolium castaneum* (Herbst) was investigated in a series of laboratory experiments. Bioassays conducted in air-tight glass chambers showed vapour toxicity and strong repellency on filter paper arena test towards all the stages used. The oil had fumigant activity against eggs and the toxicity progressively increased with increased exposure times and concentrations (Islam *et al.,* 2009). ssential oils obtained from the flowers of *Dendropanax morbifera* were extracted and the chemical composition and larvicidal effects were studied. The essential oil had a significant toxic effect against early fourth-stage larvae of *Aedes aegypti* L. with an LC_{50} value of 62.32 ppm and an LC_{90} value of 131.21 ppm. The results could be useful in search for newer, safer and more effective natural larvicidal agents against *A. aegypti* (Min Chung *et al.,* 2009)

This study explored the efficacy of leaf extract of *Jatropha gossypifolia* against second instar of *Spodoptera exigua*. The leaf extract showed insecticidal activity with an LC_{50} of 35,000 ppm (r2 = 0.978) and 26,500 ppm (r2 = 0.99) after 24 and 48 hours of expose. The detoxification activities of glutathione-s-transferase (GST), and carboxylesterase (CE) in extract-treated insects was also determined to show a inducton for CE and inhibited for GST (Khumrungsee *et al.,* 2009).

Shyamapada mandal (2010) determined the larvicidal and adult emergence inhibition activities of castor (*Ricinus communis*) seed extract against three potential mosquito vectors *Anopheles stephensi*, *Culex quinquefasciatus* and *Aedes albopictus*in India. The present findings suggest that the *R. communis* seed extract provided an excellent potential for controlling *An. stephensi, Cx. quinquefasciatus* and *Ae. Albopictus* mosquito vectors.

Bioactivity-directed investigation of root extract of *Derris scandens* has led to the isolation and characterization of a new benzyl derivative, along with ten known compounds. The insect antifeedant activity and growth inhibitory studies of these compounds were investigated against castor semilooper pest, *Achaea janata* using a no-choice laboratory bioassay. Several of the isolates displayed potent feeding deterrence and were also toxic or caused developmental abnormalities following topical administration. The new compound, derrisdione A was moderately active with an antifeedant index of 58.6 % at 10 μg/cm^3 against *A. janata* (Sreelatha *et al.,* 2010).

With the development of resistance to conventionally used synthetic insecticides, vector management has become acutely problematic. Hence more attention has been focused on botanicals. Therefore, the efficacy of extracts from rhizomes of *Curcuma aromatica* against the larvae of filariasis vector mosquitoes was assayed. From the results, *C. aromatica* could be considered as one of the powerful candidate to bring about useful botanicals so as to prevent the resurgence of mosquito vectors (Madhua *et al.,* 2010).

Roman Pavela (2010) has early reported on *Spodoptera littoralis* and *Leptinotarsa decemlineata* larvae. Significant differences in antifeedant activity were found in the highest tested dose of 500µg/cm^2, not only among individual extracts but also between both pest species tested. The highest number of larvae showed effectiveness in the range of 50–95%.

1.9 The objective of the present study

Hence an attempt has been made to investigate the bioefficacy of the selected plants extracts using different solvents against the stored product pest *Tribolium castaneum* and to identify the efficacy of promising plant extract against the polyphagous field pest *Spodoptera litura.*

The present study deals with the following aspect:

1. To investigate the ovicidal activity of the selected plants (*Cardiosperumum halicacabum, Coriandrum sativum, Mentha longifolia, Ocimum basilicum, Ocimum sanctum, Phyllanthus niruri, Pongamia glabra, Solanum xanthocarpum, Tribulus terrestris, Vitex grandifolia)*, extracts using different solvents (Hexane, Ethyl acetate, Ethanol) at different concentration levels (12.5µg/ml, 25µg/ml, 50µg/ml, 100µg/ml and 200µg/ml), against the eggs of *T. castaneum*. for 11 days)

2. To observe the oviposition deterrent activity of the selected plants (*Cardiosperumum halicacabum, Coriandrum sativum, Mentha longifolia, Ocimum basilicum, Ocimum sanctum, Phyllanthus niruri, Pongamia glabra, Solanum xanthocarpum, Tribulus terrestris, Vitex grandifolia)*, extracted with different solvents (Hexane, Ethyl acetate, Ethanol) at different concentration levels like 12.5µg/ml, 25µg/ml, 50µg/ml, 100µg/ml and 200µg/ml against 5 pairs of newly emerged adult *T. castaneum* exposed for a period of 15 days.

3. To find out the repellent activity of selected plant extracts (*Cardiosperumum halicacabum, Coriandrum sativum, Mentha longifolia, Ocimum basilicum, Ocimum sanctum, Phyllanthus niruri,*

Pongamia glabra, Solanum xanthocarpum, Tribulus terrestris, Vitex grandifolia), extracted with Hexane, Ethyl acetate, and Ethanol at different concentration levels (12.5µg/ml, 25µg/ml, 50µg/ml, 100µg/ml and 200µg/ml) against the adult bettle *T.castaneum* for a period of 1 hour.

4 To find out the insecticidal activity (LC_{50} and LC_{90}) of selected plants (*Cardiosperumum halicacabum, Coriandrum sativum, Mentha longifolia, Ocimum basilicum, Ocimum sanctum, Phyllanthus niruri, Pongamia glabra, Solanum xanthocarpum, Tribulus terrestris, Vitex grandifolia)* extracted using different solvents (Hexane, Ethyl acetate and Ethanol) at different concentration leves (12.5µg/ml, 25µg/ml, 50µg/ml, 100µg/ml and 200µg/ml) against the adult insect *T. castaneum* exposed for a period of 24 hours.

4. To investigate the ovicidal activity of the crude extracts of *Ocimum sanctum,* the promising plant species at different concentrations (25, 50, 75 and 100µg/ml) against the eggs of *S. litura* (100 eggs in each lot exposedfor a period of 11 days).

5. To investigate the oviposition deterrent activity of the crude extracts of *Ocimum sanctum,* the efficient plant species at diverse concentrations (25, 50, 75 and 100 μg/ml) against 10 pairs of adult insect *S. litura* exposed for a period of 15 days.

6. To evaluation of the pupicidal activity (LC_{50} and LC_{90}) of the crude extracts of the promising plant species, *Ocimum sanctum* at various concentrations (25, 50, 75 and 100μg/ml) against the 5th instar larvae (50 nos) of *S. litura.*

7. To evaluate the antifeedent activity of the crude extracts of *Ocimum sanctum* at various concentrations (25, 50, 75 and 100μg/ml) against the 5th instar larvae (50 nos) of *S. litura* with an exposure period of 24 hours.

8. To identify the phytochemicals present in the promising ethanolic extract of *Ocimum sanctum* by GC-MS analysis.