Introduction
INTRODUCTION

Rice is predominantly a food crop, but (unlike wheat) only 7% of rice production is traded internationally. Most rice is traded as milled rice, the weight of which is about two-thirds (67%) that of paddy rice. Dominant exporters (values shown as annual average paddy rice equivalents for the 2000s) are Thailand (8.4 Mt), Vietnam (4.4 Mt), India (4.2 Mt), the USA (3.3 Mt) and Pakistan (2.8 Mt) (Dorosh and Wailes, 2010). Dominant importers are Sub-Saharan Africa (8 Mt), West Asia (6 Mt) and the Philippines (3 Mt). Mohanty (2013) points to recent rises in India’s exports (10 Mt in 2012) and China’s imports (2.5 Mt in 2012).

Rice is grown largely in the tropics and subtropics, with only a small proportion of rice area (3%) in developed countries. Also, unlike wheat, rice area has increased over the past 30 years by 10% to reach about 160 Mha, and this area is still increasing at a rate of 0.4% p.a. of the 2008–10 area (Table 1.1). There have been notable increases in rice area in Indonesia, Myanmar, Vietnam and Sub-Saharan Africa, countered somewhat by decreases in rice area in China and South America (Table 1.1). Sub-Saharan Africa, in particular western Africa, a large rice-importing region, is now seeing quite a lift in production. The world produced on average 692 Mt of paddy or rough rice (O. sativa) in 2008–10 (FAOSTAT 2013). The largest producers, shown in Table 1.1, included China with 28% of world production, India (21%) and Indonesia (9%).

India has the largest rice area in the world (43 Mha) but yield is relatively low (3.3 t/ha) 34 Low rice yield in India is partly related to the high percentage of rainfed rice and Insect pest. Irrigated rice dominates across the Indo-Gangetic Plain from the state of Punjab in the north, to the state of West Bengal in the east and in the central state of Andhra Pradesh linking to the southern state of Tamil Nadu (FAOSTAT, 2013). According to the International Rice Research Institute (IRRI) World Rice Statistics 2004–06, India’s rice area comprises:

- 53% irrigated (RME1 and RME2)
- 32% rainfed lowland (RME5)
- 12% rainfed upland (RME6)
- 3% deepwater rice (RME7).
Rice area is steady, but the irrigated proportion increased linearly from 1960 to a peak in 2000, followed by a small decrease. Thus only some of India’s moderate FY progress of 35 kg/ha/yr since 1990—equivalent to 1.1% p.a. relative to an average 2008–10 FY of 3.3 t/ha (Table 1.1)—is likely due to an increase in the percentage of rice area irrigated (FAOSTAT, 2013).

**Table 1.1; Rice countries and Mega-environments**

Annual rice production, harvested area and yield in 2008-10 for major producing countries, and annual rates of change from 1991 to 2010

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Production (Mt)</th>
<th>Area (Mha)</th>
<th>Yield (t/ha)</th>
<th>Rate of change (p.a.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>639.6</td>
<td>100.2</td>
<td>4.32</td>
<td>0.4</td>
</tr>
<tr>
<td>China</td>
<td>195.7</td>
<td>29.8</td>
<td>6.56</td>
<td>-0.6</td>
</tr>
<tr>
<td>India</td>
<td>142.6</td>
<td>43.4</td>
<td>3.28</td>
<td>ns 0.1</td>
</tr>
<tr>
<td>Indonesia</td>
<td>63.7</td>
<td>12.8</td>
<td>4.97</td>
<td>0.8</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>48.3</td>
<td>11.4</td>
<td>4.24</td>
<td>0.6</td>
</tr>
<tr>
<td>Vietnam</td>
<td>39.2</td>
<td>7.4</td>
<td>5.27</td>
<td>0.7</td>
</tr>
<tr>
<td>Thailand</td>
<td>33.1</td>
<td>11.3</td>
<td>2.93</td>
<td>1.1</td>
</tr>
<tr>
<td>Myanmar</td>
<td>32.6</td>
<td>8.0</td>
<td>4.06</td>
<td>2.2</td>
</tr>
<tr>
<td>South America</td>
<td>24.4</td>
<td>5.1</td>
<td>4.78</td>
<td>-1.0</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>18.9</td>
<td>9.3</td>
<td>2.03</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Yield loss due to insect pests in rice in India has been estimated at 21 to 51% (Pasalu et al., 2004). Among the insect pests that attack rice crop, stem borers, gall midge, leaf folders, planthoppers, leafhoppers are very important.

Among plant hopper species found in India, the brown planthopper (BPH), *Nilaparvata lugens* (Stal) emerged as a major pest of rice in India only after 1971 with initiation of cultivation of short-statured, high-yielding and nitrogen-responsive varieties in the deltas of South India. Damage to the rice crop is caused directly by sucking on the phloem sap in rice plant and indirectly by transmitting plant viral diseases like grassy stunt and wilted stunt viruses to causing economic damage directly by producing symptoms commonly referred to as ‘hopperburn’ (Senthil Nathan et al., 2008).

Knowledge on population of insect pest in relation to changes in weather parameters, crop phenology, growing season and cropping systems is vital for designing
ecologically sound and economically viable pest management strategies. Further, knowledge on population of insect pest at a given location is also essential for implementing location specific IPM strategies and precision agriculture technologies.

In India rice is grown in different agroclimatic zones under diverse cropping systems. The population of major insect pest BPH vary under such diverse cropping systems and geographical locations. Abiotic factors like temperature, humidity, sunshine hours, rainfall etc., and biotic factors like natural enemies such as parasites and predators significantly influence the population of insect pests. Concerted efforts are being made to monitor the population dynamics of insect pests at different locations across the country every year to understand the short and long term changes in the pest scenario. The assessments of insect populations are being made using light traps.

All India Coordinated Rice Improvement Project (AICRIP) was established in 1965 by the Indian Council of Agricultural Research (ICAR) to organize national level multi-location testing of varieties and other crop management technologies across all rice growing ecologies of the country. In order to meet the objective of the technology development and evaluation, the AICRIP was elevated as the Directorate of Rice Research (DRR) in August 1975 with the added mandate of pursuing research on irrigated rice for strengthening and stabilizing rice production in the country. Currently 47 funded and over 90 voluntary centres operate under AICRIP which also forms a part of the mandate of DRR. In addition, DRR initiates network projects of national importance and coordinates these activities (AICRIP, 2013).

Since 1968, more than 990 rice varieties for various agroecological systems prevalent across the country have been released through multilocation testing, out of which 60 varieties have been developed by the Directorate. About 27% of these varieties are meant for irrigated area in medium and early duration group, 17% for rainfed shallow lands, 14% for rain fed uplands, 4.6% for irrigated areas in hills, 3.9% for irrigated mid-early, 3.7% for semi-deep water, 2.9% irrigated saline/alkaline soils, 2.6% for scented rice, 2% for deep water and rest for the other rice ecologies. The releases also include 59 rice hybrids. Of the varieties released under AICRIP, 19 are being cultivated in 25 other rice growing countries worldwide (AICRIP, 2013).
Worldwide, over 160.2 million hectares are devoted to rice cultivation. Much of this area is found in countries of the tropics and subtropics where malaria still constitutes a serious human health problem. Because rice fields are flood-irrigated, they provide ideal breeding habitat for a number of potential mosquito vectors of malaria. One of these vectors, *A. culicifacies* sensu lato (s.l.) is well established as the major vector of both falciparum and vivax malaria. Earlier studies unequivocally incriminated *A. culicifacies* as the major malaria vector, responsible for transmission of 65% of malaria cases in India (Sharma, 1998).

The mosquito *Anopheles culicifacies* is the most important rural malaria vector in India. It breeds in gentle flowing and stagnant clean waters. Responsible, for epidemic malaria for nearly 65 percent of total 2–3 million malaria cases reported annually (Sharma et al., 1999). *A. culicifacies* is predominantly zoophilic, feeding mainly on cattle (anthropophilic index less than 10%), but where cattle are scarce, its anthropophilic index can reach in excess of 20%. Various studies unequivocally incriminated *A. culicifacies* as a major malaria vector, responsible for transmission of 65% of malaria cases in India (Sharma, 1999). However, no enough studies have been carried out to block malarial parasite transmission or to induce anti-mosquito immunity in this major vector of malaria in India. *A. culicifacies* exists as a complex of five sibling species provisionally designated as A, B3, C4, D5 and E6. These sibling species are reported to have various biological differences, viz. their distribution, response to insecticides (Raghavendra, 1992), host preferences and vectorial capacity (Subbarao, 1988). *A. culicifacies* A and C are primary vectors whereas species B has very little role, if at all, in the transmission of malaria (Kaur et al., 2000).

*A. culicifacies* has been regarded as mainly endophilic with outdoor-resting behaviour reported recently in some parts of India. *A. culicifacies* is well established as the major vector of both *falciparum* and *vivax* malaria in Sri Lanka, while *A. subpictus* s.l. and certain other species function as secondary vectors. (Amerasinghe, 1992; Surendran Ramasamy, 2010).

Vector control is of serious concern in developing countries like India due to lack of general awareness, development of resistance and socio-economic reasons. Every year
a large part of the population is affected by one or more vector-borne diseases. Mosquito control, in view of their medical importance, assumes global importance. In the context of ever increasing trend to use more powerful synthetic insecticides to achieve immediate results in the control of mosquitoes, and alarming increase of physiological resistance in the vectors, its increased toxicity to non-target organism and high costs are noteworthy (WHO, 2002).

Geographic information system (GIS) technology appears to be sufficiently well developed to be integrated into existing integrated pest management (IPM) programmes. Pest-weather models can be used for agro-ecological zoning (AEZ) of pest population using GIS techniques (Raji, 2007). Pest zoning is applicable for large area pest management, in which both tactics and strategies can be merged to achieve optimal management. AEZ helps in delineating pest hot-spots and also in assessing probability of pest outbreaks in different part of a region. This study presents AEZ of BPH and A. culicifacies incidence in different Agro-Ecological Zones.

GIS software is described most correctly as "enabling technology". A GIS provides insect ecologists and pest managers with the capabilities to store, retrieve, process and display spatially referenced data. It is likely that entomologists will rapidly embrace emerging GIS technology because so many questions from insect ecology to pest management have a spatial component. Whether studying the patch dynamics of host and herbivore or predicting regional hazard, GIS technology can provide entomologists with the ability to answer questions that frustrated their predecessors. At present it is possible to identify two general areas where a GIS has been used in applied insect ecology: characterization of habitat susceptibility to outbreaks and compilation of census data.

Extensive use of synthetic chemical pesticides leads to insect resistance environmental pollution, adverse effect on human health, other organisms and the demand for reduced chemical inputs in agriculture have provided an impetus to the development of alternative forms of pest control (Murugan et al., 2012).

There is an urgent need to develop new insecticides for controlling insect pests and vectors which are more environmentally safe and also biodegradable and target-specific against the insects. The recent negative consumer perceptions concerning
the use of chemicals as larvicides has shifted the research effort towards the development of alternatives that the public perceives as natural, such as bacterial pesticides, predators and plant extracts. Consequently the present work deals with the insecticidal activities of naturals, such as plant extracts, microbes and biosynthesized nanoparticles.

Nanoparticles are also effective against insects and pests. Nanoparticles can be used in the preparation of new formulations like pesticides, insecticides and insect repellants (Barik et al., 2008; Gajbhiye et al., 2009).

Nanotechnology is a novel scientific approach that involves the use of materials and equipment capable of manipulating physical as well as chemical properties of a substance at molecular levels. On the other hand, bio-technology involves using the knowledge and techniques of biology to manipulate molecular, genetic and cellular processes to develop products and services and is used in diverse fields from medicine to agriculture (Fakruddin et al., 2012). Agriculture is the backbone of developing countries, with more than 60% of the population depending on it for their livelihood (Brock et al., 2011).

Nanotechnology has the potential to revolutionize the agricultural and food industry with novel tools for the molecular management of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients, among others. On the other hand, nanobio-technology can improve our understanding of the biology of various crops and thus can potentially enhance yields or nutritional values, as well as developing improved systems for monitoring environmental conditions and enhancing the ability of plants to absorb nutrients or pesticides (Tarafdar et al., 2013).

Some of the nano particles that have entered into the arena of controlling plant diseases are nanoforms of carbon, silver, silica and alumino-silicates. At such a situation, nanotechnology has astonished scientific community because at nano-level, material shows different properties. The use of nano size silver particles as antimicrobial agents has become more common as technology advances, making their production more economical. Since silver displays different modes of inhibitory action to microorganisms (Young, 2009), it may be used for controlling various plant pathogens in a relatively safer way compared to commercially used fungicides. Silver is known to affect many biochemical processes in the microorganisms including the changes in routine functions...
and plasma membrane (Pal et al., 2007). The silver nanoparticles also prevent the expression of ATP production associated proteins (Yamanka et al., 2005). In a nutshell, the precise mechanism of bio molecules inhibition is yet to be understood.

The study of biosynthesis of nanomaterials offers a valuable contribution into materials chemistry. The ability of some microorganisms such as bacteria and fungi to control the synthesis of metallic nanoparticles should be employed in the search for new materials (Mandal et al., 2006).

Nanotechnology emerges from the physical, chemical, biological and engineering sciences where novel techniques are being developed to probe and manipulate single atoms and molecules. The term nano is adapted from the Greek word meaning “dwarf.” When used as a prefix, it implies $10^{-9}$. A nanometer (nm) is one billionth of a meter, or roughly the length of three atoms side by side. A DNA molecule is 2.5 nm wide, a protein approximately 50 nm, and a flu virus about 100 nm. A human hair is approximately 10,000 nm thick. A nanoparticle is a microscopic particle with at least one dimension less than 100 nm. The science and engineering of nanosystems is one of the most challenging and fastest growing sectors of nanotechnology.

The physicochemical properties of nanomaterials significantly depend on their three dimensional morphologies - size, shapes and surface topography - the surrounding media, and their arrangement in space. The correlation of these parameters with the relevant physical and chemical properties is a fundamental requirement for the discovery of novel properties and applications as well as for advancing the fundamental and practical knowledge required for the design and fabrication of new materials.

Nanometre sized particles are also found in the atmosphere where they originate from combustion sources (traffic, forest fires), volcanic activity and from atmospheric gas to particle conversion processes such as photochemically driven nucleation. In fact, nanoparticles are the end product of a wide variety of physical, chemical and biological processes, some of which are novel and radically different, others are quite common.

Nanoparticles are the simplest form of structures with sizes in the nm range. In principle any collection of atoms bonded together with a structural radius of < 100 nm can be considered as a nanoparticle. These can include, e.g., fullerens, metal clusters.
(agglomerates of metal atoms), large molecules, such as proteins and even hydrogen-bonded assemblies of water molecules, which exist in water at ambient temperatures. The nano size of these particles allows various communications with bio molecules on the cell surfaces and within the cells in way that can be decoded and designated to various biochemical and physiochemical properties of these cells (Mody et al., 2009).

Nanoparticles are classified into major two types viz. organic and inorganic nanoparticles. Carbon nanoparticles are called the organic nanoparticles. Magnetic nanoparticles, noble metal nanoparticles (platinum, gold and silver) and semiconductor nanoparticles (titanium dioxide and zinc oxide) are grouped as inorganic nanoparticles. Inorganic nanoparticles are increasingly used in drug delivery due to their distinctive features such as ease of use, good functionality, biocompatibility, ability to target specific cell and controlled release of drugs.

Metallic nanoparticles (NPs) have attracted the attention of the scientific community and technologists due to their ever-emerging, numerous, and fascinating applications in various fields, including biomedical sciences and engineering. Gold and silver have a broad absorption band in the visible region of the electromagnetic spectrum (Kreibig and Vollmer, 1995; Mulvaney, 1996). The properties of these metals changes, which depends upon their shape, size, and the surrounding medium, and they have been used in advanced technologies in medicine, opto-electronics and chemical catalysis, in sensors, for drug delivery, and for etching and cutting (Che and Bennett, 1989; Elghanian et al., 1997; Haruta, 1997; Valden et al., 1998; Fujimoto, 2003; Kruising, 2004; El-Sayed et al., 2006; Aurel et al., 2007; Jain et al., 2009).

Silver is a naturally occurring precious metal, most often as a mineral ore in association with other elements. It has been positioned as the 47th element in the periodic table, having an atomic weight of 107.8 and two natural isotopes 106.90 Ag and 108.90 Ag with abundance 52 and 48%. It has been used in a wide variety of applications as it has some special properties like high electrical and thermal conductivity (Nordberg and Gerhardsson, 1988).

Silver is widely known as a catalyst for the oxidation of methanol to formaldehyde and ethylene to ethylene oxide (Nagy and Mestl, 1999). Colloidal silver has particular
interest because of distinctive properties, such as good conductivity, chemical stability, catalytic, antibacterial and antimicrobial activity (Frattini et al., 2005; Bhainsa and D’Souza, 2006). For centuraries silver has been in use for the treatment of burns and chronic wounds. As early as 1000 B.C. silver was used to make water potables (Richard et al., 2002; Castellano et al., 2007). In 1700, silver nitrate was used for the treatment of venereal diseases, fistulae from salivary glands and bone and perianal abscesses (Klasen, 2000; Landsdown, 2002).

The optical properties of spherical silver nanoparticles are highly dependent on their diameter. As the size of the silver particles increases, its unique plasmonic signature shifts towards the red region of the visible spectrum and both the dipole and quadrupole peaks are clearly expressed. The total optical extinction is comprised of absorption and scattering. At small particle size silver nanoparticles are primarily absorbing and have a clear yellow color in solution. As the silver particles get larger, the scattering portion of the extinction increases. This increase in the scattering component results in the solution becoming grayer in color. Nanoparticles have found usage in many applications such as catalysis, sensors, drug delivery, opto-electronics and magnetic devices (Aurel et al., 2007; Chan and Nie, 1998; Vaseashta and Dimova-Malinovska, 2005).

Nanoparticles of a wide range of materials can be prepared by a variety of methods that include atomic manipulation with scanning probe methods, self-organized growth, and the controlled deposition of nanoclusters from the gas phase (Bromann et al., 1996). In this study, we describes a rapid and eco-friendly method for bio synthesis of silver nanoparticles using fungal extract of *M. anisopliae* and plant extract of *E. axillare* as both the reducing and stabilizing agent and demonstrate its suitability for synthesis of silver nanoparticles.

Biosynthesis of nanoparticles is a kind of bottom up approach where the main reaction occurring is reduction/oxidation. The microbial enzymes or the plant phytochemicals with anti-oxidant or reducing properties are usually responsible for reduction of metal compounds into their respective nanoparticles.

*Metarhizium anisopliae*, formerly known as *E. anisopliae* (basionym), is a fungus that grows naturally in soils throughout the world and causes disease in various insects by
acting as a parasitoid. It is formerly classified in the form class Hyphomycetes of the form phylum Deuteromycota. *M. anisopliae* does not appear to infect humans or other animals and is considered safe as an insecticide (Donald and McNeil, 2005). Entomopathogens of *M. anisopliae* is well characterized in respect to pathogenicity to several insects and have been used as myco-biocontrol agents for biological control of agriculture pests worldwide. *M. anisopliae* produces several toxic secondary metabolites, the precise role of which in pathogenesis and virulence (Gillespie and Claydon, 1989).

Microbes are used in nanotechnology for producing nanoparticles and present green synthesis has shown that the environmentally caring and renew-able source of fungi used as an effective reducing agent for the synthesis of silver nanoparticles (Soni and Prakash, 2013). For example, bacteria *P. strutzeri* isolated from silver mine materials is able to reduce Ag+ ions and accumulates silver nanoparticles, the size of such nanoparticles being in the range 16–40 nm, with the average diameter of 27 nm.

The metabolic activity of microorganisms can lead to precipitation of nanoparticles in external environment of a cell, the fungi being extremely good candidates for such processes. The extracellular synthesis of silver and gold nanoparticles by the fungus *Colletotrichum* sp. (Mandal *et al.*, 2006) or *A. fumigatus* has been reported. A novel biological method for synthesis of silver nanoparticles using *Vericillum* was proposed by Mukherjee *et al.* (2001, 2002) a two-step mechanism was suggested. The first step involves trapping of Ag+ ions at the surface of the fungal cells. In the second step, enzymes present in the cell reduce silver ions.

The extracellular production of metal nanoparticles by several strains of the fungus *F. oxysporum* has been described by Duran *et al.* (2005). The presence of hydrogenase in the *F. oxysporium* broth was demonstrated. This extracellular enzyme shows excellent redox properties and it can act as an electron shuttle in metal reduction. It was evident that electron shuttles or other reducing agents (e.g., hydroquinones) released by microorganisms are capable of reducing ions to nanoparticles.

Paddy weed, *Enicostemma axillare* (Lam) Raynal (Synonym, *E. littorale* auct. Non Blume), family Gentianaceae is a glabrous or procumbent perennial herb found throughout India, especially in coastal regions. In Indian traditional medicine, the plant is
being used as anti-inflammatory, digestive, thermogenic and liver tonic and used to treat diabetes mellitus, rheumatism abdominal ulcers, hernia, swelling, itches and insect poisoning (Varier, 1994). The medicinal use of natural products has played a very important role in treatment of many diseases and insecticidal activities. The aim was to demonstrate the reducing effect of *E. axillare* in the biosynthesis of silver nanoparticles.

Many studies have highlighted the fact that phytochemical constituents present in the plant extracts play a major role in the reduction of silver ions into metallic silver and subsequent capping to prevent agglomeration. One of the important groups of phytochemicals, that is flavonoids have proven to be have pharmacological properties like anti-inflammatory, anti-allergic, anti-bacterial, and anti-viral properties (Cook and Samman, 1996; Murray, 1998; Cushnie and Lamb, 2005) and have also been found to have cytotoxic antitumor properties and to be effective in neurodegenerative diseases (de Rijke *et al.*, 2006; Chebil *et al.*, 2006). Flavonoids are free radical scavengers acting as antioxidants against free radicals (Pal *et al.*, 2009). Natural antioxidants that are present in herbs and spices are responsible for inhibiting or preventing the deleterious consequences of oxidative stress. Spices and herbs contain free radical scavengers like polyphenols, flavonoids and phenolic compounds. Flavonoids prevent synthesis of PGs that suppress T-cells (Bitis *et al.*, 2010); there are a huge number of research studies done, in which silver nanoparticles are synthesized using plant extracts rich in flavonoids.

Hence, the present study mainly concentrated on the distribution of *Nilaparvata lugens* and *Anopheles culicifacies* in varied Agro-Ecological Zones of South India, using Geographical Information System (GIS) model. The present Investigation also to study on the synthesis and Characterization of green and fungal mediated silver nanoparticles using plant, *Enicostemma axillare* and fungi, *Metarhizium anisopliae* for the control of Brown Pnathopper, *Nilaparvata lugens* and rural malarial vector, *Anopheles culicifacies*. 