INTRODUCTION
Chapter I

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Rice (Oryza sativa L) is a cereal grain of the grass family (Graminae) and belongs to the genus Oryza under the tribe Oryzeae. The genus Oryza includes 23 wild species and 2 cultivated species (cultigens) native to the deltas of the great Asian rivers—the Ganges, the Chang (Yangtze) and the Tigris and Euphrates. Rice was introduced to the American colonies in the mid-17th century and soon became an important crop (Anon. 1976). Although U.S. production was less than that of wheat and corn, rice was grown in excess of domestic consumption was exported, mainly to Europe and South America. At present the world's leading rice-producing countries are China, India, Indonesia, Bangladesh, and Thailand.

Rice was introduced to India before the time of the Greeks. Chinese records of rice cultivation goes back to 4,000 years. In classical Chinese, the words for agriculture and for rice culture were synonymous, indicating that rice was already the staple crop at the time the language was taking form. In several Asian languages the words for rice and food are identical. Rice is a staple food for over half of the world’s population. More than 90 % world’s rice is produced and consumed in Asia (Sigsgaard 2000) suggesting its dominance in the developing world. Among the food grains
cultivated in India, rice ranks first both in terms of area (37 mha) as well as production (80 mt) in 2010-11 (Anon. 2010).

Rice can be grown in almost all types of soils. The soils most suited for the cultivation of rice are clay, loam and dry soils. Such soils are capable of holding water for long period. Rice is more suited to high rainfall regions because it requires abundant moisture either through rainfall or irrigation to keep the soil under saturation throughout its life period. Therefore, the practice of rice cultivation is mostly dependent on the rainfall especially in northern and central India. In addition other climatic factors that influence rice production are temperature, photoperiod, day length and humidity.

Temperature requirements vary according to phenology and biology of the crop. For example, during flowering, it should range between 16 to 20 °C, whereas during maturity it again ranges between 28 to 32°C. However, the temperature beyond 35°C affects grain filling. During panicle initiation, 20 to 22°C is ideal. The temperature below or above this range will adversely affect the crop growth and yield. Day length or Sunshine is another important factor for growth and development of the crop, which is the source of energy for plant life. The grain yield of rice is influenced by the solar radiation particularly during the last 35 to 45 days of its ripening period. The effect of solar radiation is more profound where water, temperature and nitrogenous nutrients are not limiting factors. Bright sunshine with low temperature during ripening period of the crop helps in the development of carbohydrates in the grains. (Anon. 2011)
Rice is grown in varied eco-systems viz. rainfed/irrigated upland and lowland, flood-free and flood-prone, medium land, deep water and hill eco-system. In low land cultivation, transplanting is done whereas in other systems direct seeding is done. Generally low land rice refers to rice grown on low lying areas where water can be collected and retained by artificial irrigation, rainfall or a flooded river to keep the soil constantly submerged at the appropriate growing period of the crop.

The manure and fertilizer requirement varies among seasons. Rice grown in *Ahu* season (Feb/March - June/July) requires 10 ton, 88 kg, 125 kg, 32 kg/ha farm yard manure (FYM), urea, single super phosphate (SSP) and murate of potash (MOP) respectively. *Sali rice* (June/July - Nov/December) requires 10 ton, 132 kg, 125 kg 66 kg/ha FYM, whereas *bao* rice (Nov/December - May/June) requires urea 134 kg, 254 kg and 67 kg/ha urea, SSP and MOP respectively (Anon. 2009).

In India, rice covering more than 30% of the total cultivated area contributing about 42% country’s food grain production. Rice not only forms the mainstay of diet for majority of its people, but also is the livelihood for over 70% of the population.

In Assam, more than 90% population depend on rice for the caloric requirement. Geoclimatic variations and agriculture's dependence on rainfall have resulted in three distinct rice growing seasons in Assam viz., *ahu or autumn rice*, *Sali or winter rice* and *boro* or summer rice. In Assam, rice is grown for about 25.30 lakh ha area with a productivity of 1765 kg/ha (Anon. 2009-10) which is lower than that of national average (1930kg/ha). The world population is currently estimated to be 7
billion, and at current growth rate the global world population is expected to reach 9 billion people by the year 2050. More than 65% (5.6 billion) of the world population live in developing countries and is projected to rise 9 million in 2050 (PRB, 2011). Obviously, for sustaining such a huge population, the developing countries require large amount of food and fibers from shrinking agricultural land base. To meet this high demand of food and fibers, intensification of agriculture with modern techniques has been widely employed in these countries. Although the modern agricultural practices increased crop production; it also enhanced severe insect pest out breaks, disease and weeds in agricultural crops (Koul and Walia 2009). The yield loss caused by insect pest infestation has been estimated to be about 20% (Pathak and Dhaliwal 1977, Singh and Dhaliwal 1994). This loss amounts to approximately U. S. $ 100 million in India alone (Murulidharan and Pasalu 2006).

Over 100 insect species attack and damage rice crop in various growth stages (Pathak 1968, 1977; Grist and Lever 1969, Beevi et al. 2002). Many of them often appear sporadically and do not cause economice loss (Murulidharan and Pasalu 2006). A few species, however, do cause significant damage and are extremely important. These insect pests are known to attack rice crop during different growth stages of which about 20 have major significance. In India, 18 species of stem borer in the family of Pyralidae and 3 species in the family of Noctuidae have been recorded (Banerjee 1964, Kapur 1967). The predominant species in India includes *Scirpophaga incertulas* Walker (Lepidoptera: Pyralidae), white stem borer *Scirpophaga innotata* Walker (Lepidoptera: Pyralidae), stripped stem borer *Chilo suppressalis* Meyricka
(Lepidoptera: Pyralidae) and pink stem borer *Sesamia inferans* Walker (Lepidoptera: Noctuidae). *S. inferans* primarily restricted to hill regions of Northern and North Eastern states of India (Murulidharan and Pasalu 2006). The estimated loss for stem borer varies from 3-95% (Ghose *et al*.1960) with an estimated annual loss of $10 million (Mehta and Varma 1968). Damage during vegetative phase contributed shares about 50 % which is more than damage in the reproductive (30%) and ripening phase (20 %) (Litsinger *et al*. 1987). With the advent of green revolution, introduction and extension of area under high yielding varieties and use of higher dose of nitrogenous fertilizers, leaf hopper *Nephotettix nigropictus* Distant and *N.virescens* Distant (Homoptera: Cicadelidae) and plant hopper *Sogatella furcifera* Horvath (Homoptera: Delphacidae) altered their pest status to a major one. Other important insect pests of rice in India include rice gall midge *Orselia oryzae* Wood-Msoon (Diptera: Cecidomyiidae), leaf folder *Cnaphalocrosis medinalis* Guenee (Lepidoptera: Pyralidae), rice bug (*Leptocorisa acuta* Thunberg and *L. oratorius* Thunberg (Hemiptera: Coreidae), rice hispa *Dictadispa armigera* Olivier (Coleoptera: Chrysomelidae), thrips *Stenochaetothrips biformis* Bagnall (Thysanoptera: Thripidae), case worm *Nymphula depunctalis* Guenee (Lepidoptera: Pyralidae), whorl maggot *Hydrellia philippina* Ferino (Diptera: Ephydridae), army worm *Mythimna separata* Walker (Lepidoptera: Pyralidae). These insect pests having different damage potentials are known to attack rice crop during different growth stages.

Among the major insect pests of rice, the rice hispa *D. armigera* is one of the most important constraints to crop production globally. It is a major pest of many rice
growing parts of Southern Asia more particularly India, Bangladesh, Mayanmar, Indonesia, Nepal, Cambodia, China, Pakistan, Sri Lanka, Malaysia and Australia. It was known to be a sporadic pest of paddy in the states like Andhra Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal. In recent years, it has assumed the major pest status in some areas of Assam, Bihar, Uttar Pradesh, Himachal Pradesh, Orissa and Tamil Nadu (Hazarika et al. 1998, DRR 2009, Pasalu 2011 Hazarika and Puzari 1990, Karim 1986, Khan and Murthy 1954, Sen and Chakravarty 1970, Sharma and Verma 2011). In recent years incidence of rice hispa is on increase, particularly in the wet season. Pest population buildup is favoured by rainy and cloudy days (Bhattacharjee and Ray 2010). In case of severe damage entire crop bears whitish look and leaves soon dry up and turn yellow. Rice hispa causes yield losses up to 20% in Andhra Pradesh (Pasalu and Tewari 1989), 50% in Bihar (Agarwala 1955), and 24% in West Bengal during 1970 to 1980 (Pasalu and Tewari 1989). There has been a decline in its incidence in Andhra Pradesh since 1985, except occurring sporadically. In 2007, the pest occurred in severe form at Khawala Trind and Dhanotu village of Kangra district of Himachal Pradesh causing reduction in yield up to 34.3% (Kaushik et al. 2007).

It attacks the vegetative stages of summer rice causing 35-65% loss in yield throughout Assam (Rajak et al. 1986, Hazarika and Dutta 1991) and hence it is regarded as one of the major limiting factors in rice production in Assam (Hazarika and Dutta 1991, Puzari and Hazarika 1992) (Plate 1). Under post flooded situation
Plate 1: Rice hispa, Dicladispa armigera Olivier (Coleoptera: Chrysomelidae)
when the rice crop is transplanted late, it suffers 100% loss (Deka and Hazarika 1999). It feeds primarily on rice. But it also feeds other crops like maize, wheat and sugarcane and several grasses and sedges belonging to the family Poaceae, Cyperaceae and Commelineaceae (Dutta and Hazarika 1995). Nearly 10 alternate hosts support rice hispa to build up a population sufficient enough to cause outbreak in the main host, rice of which *Andropogen gayanus*, *Chrysopogon sp.*, *Carex sp.*, *Sorghum halepense*, *Imperata cylintrica* and *Themeda anathera* were reported (Dutta and Hazarika 1995 Choudhary et al. 2002). Adult beetles feed on leaves by scraping the upper parenchymatous tissues and leave characteristic white streaks along the leaf axis, while the larvae are internal feeders and tunnel the young leaves. It has four larval instars which finally pupate inside the feeding tunnels.

Management of rice hispa is now a major problem among the farmers in NE India who depend primarily on rice as a major crop. Due to heavy rain and pest’s occurrence in large areas concurrently, pesticides have been reported to fail to have produced desirable effects. In such situation farmers used pesticides at indiscriminately higher dose. Such large-scale indiscriminate application of pesticides invites several unwanted social and environmental problems (Hazarika and Puzari1997, Deka and Hazarika 1995). For instance, synthetic insecticides cause health problems to the farm operators, consumers and the environment as well (Dubey et al. 2011). Pesticides are the most powerful tool available for rice pest management which is curative and reliable when pest population approaches economic threshold level. In the WTO regime, it is absolutely necessary to limit the usage of chemical
pesticides to remain in the world market and sustain the competition. In India crop wise market share of pesticide usage indicate the highest use pattern to the extent of 45% in cotton followed by 22% in rice, 9% in vegetables, 7% in plantations, 4% each in wheat and pulse and 9% in others. Compared with usages of chemical pesticides, biopesticides constitute around 2% in the country (David V. Vasantraj 2008). However, the pest management system in present day context demands careful and compatible integration of chemical, biological and cultural techniques in order not only to reduce environmental and ecological hazards of pesticides but also to increase economical benefits. In this regard to tackle the major pests and diseases of crops, biorational approaches are gaining momentum. Mounting concern about environmental safety and ill effects caused by chemical pesticides has led us to focus attention on biorational approaches by involving biocontrol means and judicious use of safer pesticides including botanicals. In order to evolve sustainable eco-friendly management strategy, it is essential to incorporate such technologies of pest management, which are permanent in nature and cause minimum or hardly any ill effects on the environment. Microbials are the beneficial and ecofriendly fungi, bacteria, virus and protozoans capable of killing specific pests, disease causing microbes, nematodes and are considered as potential biological alternatives in ecofriendly agriculture. The use of microbes is highly sustainable and can contribute to increase the productivity and profitability in agriculture. They are safer, economical and reliable control agents of crop pests. India is gifted with a rich biodiversity of several fungal, viral, and bacterial, protozoan and entomopathogenic nematodes of crop pests, which offer a great scope in the microbial control of crop pests. Microbial
pesticides are safe to mankind and its livestocks; do not pollute the environment and safe to the beneficial parasitoids and predators and generally there is no chance of development of resistance to these microbes. The different classes of biopesticides include biochemical pesticides, microbials pesticides and plant-incorporated protectants. They are usually inherently less toxic than conventional pesticides and generally affect only the target pest and closely related organisms, in contrast to broad spectrum, conventional pesticides that may affect other organisms as well. Biopesticides are often effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding pollution problems caused by the conventional pesticides. When used as a component of integrated pest management (IPM) programmes, biopesticides not only reduce damage caused by pests, but also enhance crop yield (Ware 1994).

Presently, biopesticides represents approximately 4.5 % of the world insecticides sales. The growth rate for biopesticides over next ten years has been forecast at 10-15 % per annum in contrast to 2.5 % for chemical pesticides. About 700 products of different microbials are currently available worldwide. In India about 16 commercial preparations of *Bacillus thuriengiensis*, 38 fungal formulations based on *Beauveria* and *Verticillium*, and about 45 baculovirus-based formulations of *Helicoverpa armigera* and *Spodoptera* are available (David V.Vasantraj 2008).

*Beauveria bassiana* (Bals.) Vuill. is a naturally occurring potent entomopathogenic fungus which has been successfully utilized for controlling many insect pests of rice globally. Incorporation of this agent may bring about a revolution
in rice pest management in Assam. Field performance of this agent is very encouraging not only in terms of the pest suppression but also in increasing yield, thereby fetching higher economic returns to the farmers compared to the conventional insecticides. In this context, success achieved at AAU in developing a mycoinsecticide, *Beauveria bassiana* (Bals.) Vuill for the management of rice hispa may be mentioned (Hazarika and Puzari 1990, 1991, 1995, 1997, Hazarika et al.1998, Hazarika 1999). However, technologies for mass production in an economical liquid medium are yet to be developed. Furthermore, formulation of the same with improved shelf life is also essential for delivery for large scale application by the farmers. Therefore the present investigation was carried out with an aim to produce a commercial formulation of *B. bassiana* with the following objectives:

1. Identification of superior stain of *B. bassiana*

2. Development of efficient formulation of the propagules with a shelf of more than 12 months.

3. Field persistence of formulation up to 15 days.

4. Impact of the formulation on non target organisms of the rice ecosystem.