1.Introduction

Faced with increasing population and shrinking agricultural land space, India, like other developing nations, needs to increase its production of food. Essential food items of daily users are sourced from horticultural produce. Since independence India has made a significant progress in bringing more land area under the cultivation of these crops. Exotic, high-yielding and good quality varieties have also been introduced in different parts of India.

Despite the developments, India has not yet been able to tackle the loss of nutritional value of food items between harvesting and consumption. According to the estimates of the Indian National Commission on Agriculture, fruits and vegetable suffers huge loss of their nutritional value due to lack of proper infrastructure and inadequacies in post harvest handling, transportation, storage and marketing. Postharvest decay results in major losses of fruits and vegetables (Janisiewicz and Korsten, 2002). In developing countries, losses of fruits and vegetables during post-harvest fluctuate between 20 and 50% (Eckert and Ogawa, 1985; Kader, 1992; Okezie, 1998). The value of this loss amounts to millions of rupees annually. The post-harvest losses have far-reaching effects in that they affect both the health of the population and the country's economy. Although synthetic fungicide treatment has been the main method for controlling postharvest diseases (Panneton *et al.*, 2001; Ippolito & Nigro, 2000, Eckert and Ogawa, 1988), there is growing international concern over the indiscriminate use of synthetic fungicides on crops because of the possible harmful effects on human health (Norman, 1988) and the emergence of pathogen resistance to fungicides (Holmes and Eckert, 1999). Thus there was a worldwide trend to explore new alternatives in order to reduce the use of synthetic fungicides (Bautista-Banos *et al.*, 2006).

India is one of the leading producers of tropical and subtropical fruits in the world. India is the largest producer of mango and banana, 2nd largest producer of litchi, 3rd largest producer of papaya and 4th largest producer of orange. However, this high production will have significance only when it reaches consumers in good condition. Faulty handling practices coupled with underdeveloped and exploitive marketing systems results in 25-30% postharvest losses and value deterioration, leaving little quality

surpluses for export and processing. Primary causes of losses include physical injuries, shriveling, contamination with pathogenic fungi and bacteria, and pesticides and chemical residues. Lack of awareness, knowledge and skills of produce handlers and marketers, aided by high ambient temperature and non-availability of efficient cool chains, further aggravate post harvest losses. Moreover, in India, the logistic chain and marketing chains of fresh fruit are very long and complicated leading to a high degree of distribution hazards. Suitable types of packaging materials need to be developed to enable fresh produce to reach destinations in a safe and sound condition. In India, the cool chain system for horticultural crops remains unorganized. There is an urgent need to develop national level planning to develop cool chain systems that are co-factoring dependent, requiring an integration with infrastructural development including reliable and consistent electricity and water supplies as well as improved road net works. This paper outlines present practices followed for harvesting, packaging, transportation and marketing of three major fruit crops, namely mango, banana, and litchi in West Bengal, India and also suggests immediate steps that must be taken to reduce postharvest losses (Mitra, 2008.).

Sub-Himalayan West Bengal popularly known as North Bengal is situated in between the mighty Himalayas and the sacred river Ganga. North Bengal stretches to the east up to the border of Bangladesh and Assam and to the west up to Bihar and Nepal. It comprises old alluvial, terai and hill zones distributed in six districts of West Bengal viz. Cooch Behar, Jalpaiguri, Darjeeling, Malda, Dakshin Dinajpur and Uttar Dinajpur. Location of North Bengal is between $24^0$74' N to $27^0$25' N latitudes and $83^0$07'E to $84^0$40'E longitudes.

North Bengal is endowed with diverse natural resources. Its ecological conditions make possible production of tropical and subtropical fruit crops. Major horticultural crops of North Bengal are orange, tomato, pineapple etc. During the last two decades, there has been a great development in cultivation and production of horticultural products. As tropical and subtropical fruits are perishable due to their characteristic shapes, structure, high water content, appearance, physiological characteristics and growing conditions, the harvested crop losses are also very high. All the three plants mentioned above are affected by several fungi. The production of the crops depends largely upon improved

technologies befitting to the agro climatic and socio-economic characteristics of this region. Research and application of technology for storage, transport, and packaging of fruits after harvest are behind production growth in this region and many tropical and subtropical fruits have not been studied and handled adequately.

Fruits are an important part of the human diet because they supply essential nutrients such as vitamins and minerals and they are also considered important to human health and well-being because they contain other necessary compounds such as antioxidants. Increased consumer awareness about diet and health has resulted in a greater consumption of fruits. Consumers are also concerned about the safety of the fruits they eat, and want foods free from pesticide residues, toxins and harmful microorganisms (Liu *et al.*, 2004; Bounous *et al.*, 2009)

Orange (*Citrus reticulate*) is one of the major commercial fruit that is widely consumed both as fresh fruits and juice. Its global demand attributed to its high vitamin content and high antioxidant potential (Gorinstein *et al.*, 2001). Orange is mainly cultivated in sub tropical and tropical regions of the world in over 137 countries and six continents (Ismail and Zhang, 2004). Orange is attacked by several plant pathogens and that affect its fruit quality. The citrus fruit is attacked by a number of pathogens from bloom to harvesting stage and subsequently by post-harvest pathogens that affect the production of the crop and considerably deteriorate the fruit quality. The incipient infection of pre-harvest pathogens subsequently also manifest in the form of post-harvest diseases besides the attack of other post-harvest wound pathogens viz. *Penicillium digitatum, P. italicum, Geotrichum candidum Fusarium moniliforme and Xanthomonas citri* etc (Naqvi, 2004).

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable worldwide, in terms of the amount of vitamins and minerals it contributes to the diet. Tomato is susceptible to postharvest diseases caused by various pathogenic fungi. *Alternaria alternata* is a saprophytic pathogen of tomato causing post harvest losses at high frequency (Akhtar *et al.*, 1994). Fungi like *Alternaria alternata* and by *Botrytis cinerea* are the limiting factors for commercialization of tomato (Jones *et al.*, 1993; Wang *et al.*, 2008). Fajola (1979) studied post-harvest fruit rot diseases of tomato were conducted in five states of Nigeria. During severe infections, the diseases could cause

25% loss at harvest and 34% loss of the remaining product in transit, storage and market stalls; thus giving an overall loss of about 50% of the product. Two types of rots, soft and dry were recognized. *Rhizopus oryzae, R. stolonifer, Fusarium equiseti, F. nivale* and *F. oxysporum* were established as the soft rot pathogens; while *Aspergillus aculeatus, A. flavus, Cladosporium tenuissimum, Corynespora cassiicola, Curvularia lunata, Penicillium expansum P. multicolor* and *Rhizoctonia solani* were established as the dry rot pathogens of tomato fruits in Nigeria. The bacterium *Pseudomonas syringae pv. tomato* synonymously known as *Pseudomonas tomato* causes bacterial speck disease on tomatoes (*Lycopersicon lycopersicum*).

Pineapple (*Ananas comosus*) is the third most important tropical fruit worldwide after banana and citrus. As much as seventy percent of the pineapple produced in the world is consumed as fresh fruit in the country of origin (Bartholomew *et al.,* 2003). Pineapple is consumed due to its pleasant taste and flavor. The fruit is also a good source of vitamin A, B, C, minerals (calcium, magnesium, potassium, iron etc.) and of a digestive enzyme (bromelin). Various diseases have been reported to be causing severe losses in pineapple and they have been considered as one of the constraints for low yield of pineapple in several areas. Wilson *et al.,* (2005) reported that Black rot of pineapple, caused by *Chalara paradoxa* (De Seyn.) Sacc., is a postharvest disease responsible by high losses on fruits destined to the fresh market and to the processing industry. Pink disease is a bacterial infection of the pineapple fruit, characterize by the development of a brown color in the flesh resulting from the processing of fruits infected by *Acetobacter aceti, Erwinia herbicola* and *Gluconobacter oxydan, Erwinia carotovora.*

Reducing post-harvest losses is a major challenge to the hungry and increasingly competitive world. Many factors contribute to post-harvest losses in fresh fruits and vegetable (Liangji, 1999). Extreme climatic conditions like heat and drought, mechanical damage, improper sanitation are major contributing factors to the losses directly or by inducing disease. Chemicals have been widely used to prevent the diseases. Fungicides and bactericides have been used in the past to prevent the transmission of disease (Wojciech and korsten, 2002).

Increasing public concern and proliferation of resistance in the pathogen populations are the two major obstacles of using chemical fungicides (Sharma and

Meshram, 2006; Cutler and Cutler, 1999; Janisiewicz, 1997; Chalutz and Droby, 1998; Wisniewski and Wilson 1992; Wilson and Wisniewski, 1989; Caia *et al.*,1988; Utkehede and Sholberg, 1986). Many countries don't allow importation of produce that has treated with fungicides. There is an urgent need of alternative economical safe, effective non pesticides treatments for disease control in fresh horticulture crops (Patni *et al.*, 2005). At present there is an all-round compulsion among the multinational companies and other agencies to go in for bio-rational alternative arsenal, which can be eco-friendly and benign to environment (Saha *et al.,* 2005a; 2005b).

Over the last two decades, biological control of plant pathogens has emerged as a viable disease control strategy (Elad & Stewart 2004; Harman 2000). Biological control of plant diseases involves the use of one nonpathogenic organism to control or eliminate a pathogenic organism. Hence, biological control has attracted a great interest in plant pathology (Goto, 1990) and it becomes important to develop cheaper management practices to control disease and obtain higher yield.Biological control has been explored as one of the possibilities to control post harvest diseases too. Biological control of post harvest diseases using antagonists has been extensively studied. Several authors have reported antagonistic activity of microorganisms in different crops (Droby *et al.*, 1992; Prasad *et al.*, 1999; Meena *et al.,* 2000; Dwivedi and Johri, 2003; Jadeja, 2003; Kohli and Diwan, 2003; Vestberg *et al.*, 2004; Brewer and Larkin, 2005; Sudha *et al.*, 2005; Singh and Sinha, 2005).

Several plant extracts have been reported to possess substances that are toxic to microbial pathogen. Plants with medicinal properties have also been reported to possess antifungal properties (Raghab, 2003; Bowers and Locke, 2000). Botanical fungicides broadly comprise of secondary metabolites from microbes and higher plants. Based on their mode of action secondary metabolites of higher plants are classified as photochemical with antifungal action. There are evidences of applying phytochemicals in various plants to check different fungal diseases (Rana *et al.,* 1999, Natarajan *et al.,* 2001, Hu *et al.*, 1999). Out of more than 2 lakh higher plant species that exist on earth only relatively few have been thoroughly studied for their therapeutic potential (Deans and Svoboda, 1990). Currently plant products are targeted, as they comprises a rich store house of biochemical's that could be tapped as for use as pesticides. About 10,000

secondary metabolites of about more than 4 lakh plant chemicals known have role in controlling plant pathogens. Numerous defensive chemicals, such as terpenoids, alkaloids, phenols, tannins are very effective in the control of phytopathogenic fungi and bacteria. Even though many antifungal and antibacterial compounds are reported in literature, plant products have not been used to any significant extent in the development of antimicrobial fungicides (Narashimhan and Masilamani, 2002). Natural plant extracts may provide an environmentally safer, cheaper and more acceptable disease control approach (Dixit *et al.,* 1995).

The study aims to assist the local and export market of North Bengal for the benefits of grower as well as to increase consumer satisfaction. The study investigates the ways in which the use of conventional fungicides can be reduced as a post harvest treatment of these fruits and can be replaced with the safe compounds of low or no residual effect. In this study we investigated the use of botanicals and antagonists to control the post harvest diseases.

The basic objectives of the present study are:

1. Screening of post harvest disease causing organisms of tomato, pineapple and orange.
2. Isolation and purification of the disease causing organisms.
3. Physiological characterization of selected pathogenic organisms.
4. Elucidation of the chemical structure of the bioactive antifungal component.
5. Control of the organisms by antagonistic microorganisms and bioformulation.
6. Screening, identification and formulation of botanicals for control of the pathogens and bioformulation.
7. Use of bioformulations for control of the post harvest diseases of tomato, pineapple and orange.

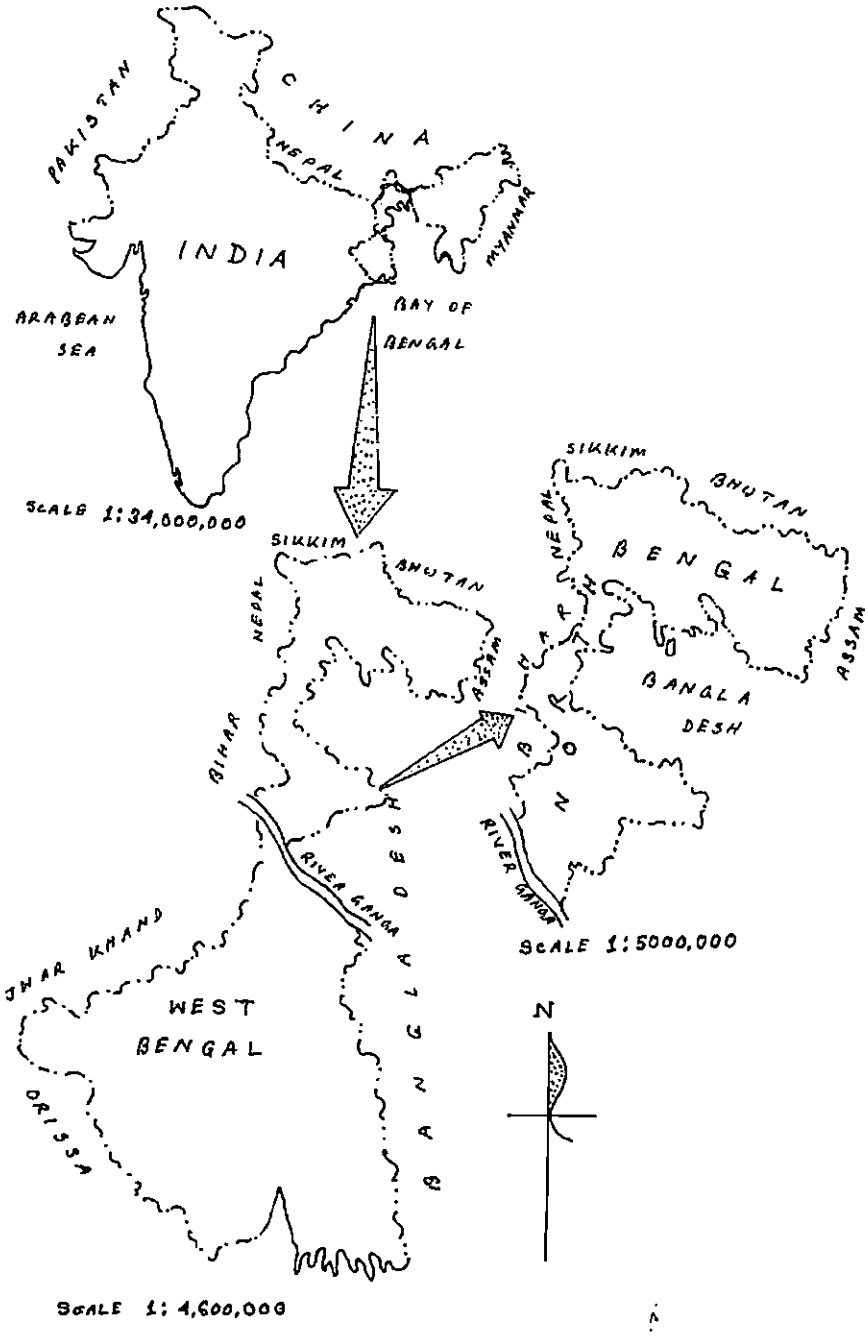

Fig: 1. Map showing present study area in India

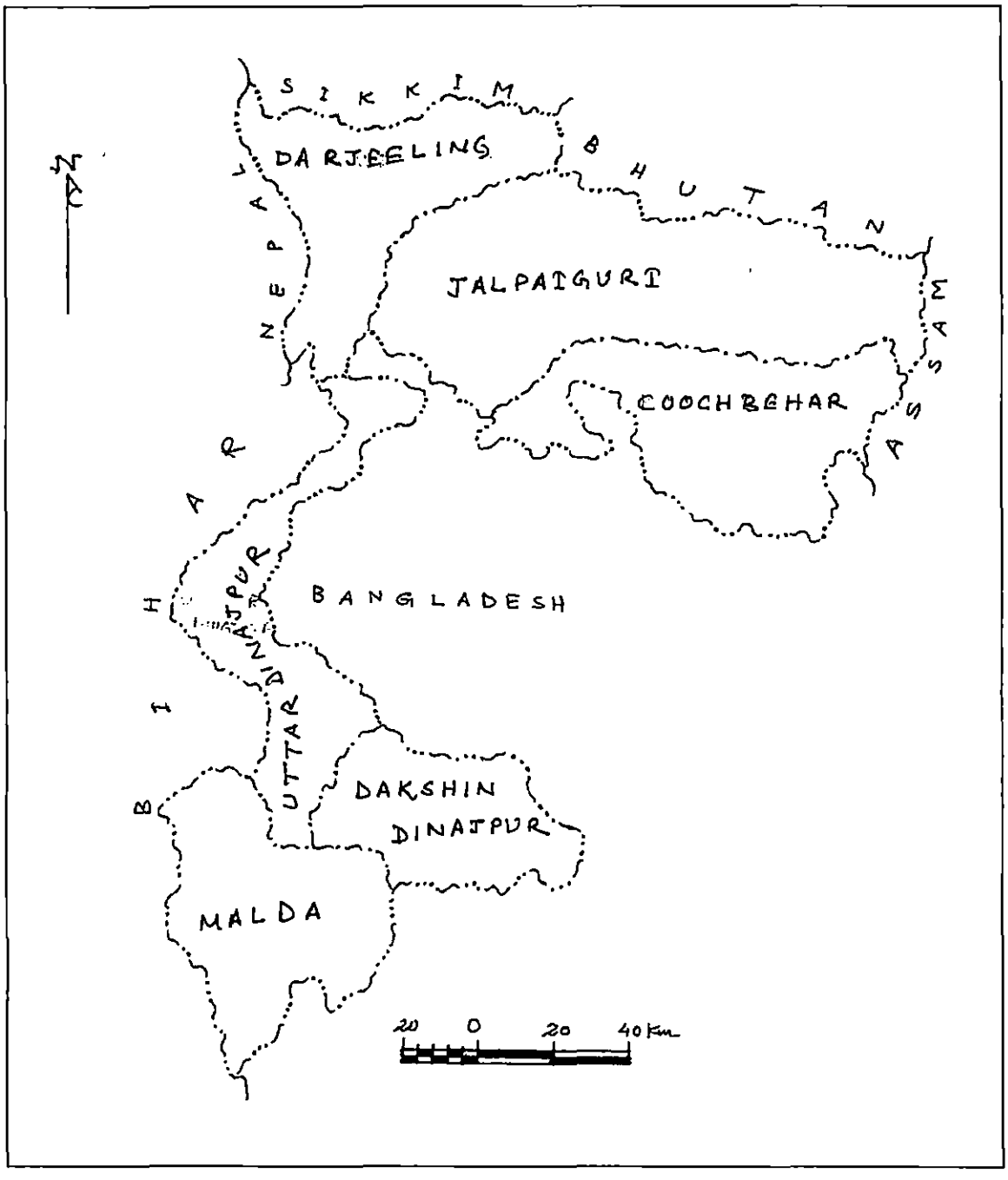

Fig: 2. Highlighted areas of the map showing present study areas in North Bengal.