Introduction

The banana is one of the oldest fruit known to mankind and it is called “Apple of Paradise”. Its antiquity can be traced back to the Garden of Paradise where Eve was said to have used its leaves to cover her modesty. It has been frequently mentioned in the great Indian epics, Ramayana and Mahabharata. Edible Musa spp. originated in south eastern Asia, from India east and south to northern Australia. Early Filipinos probably spread the banana eastward to the Pacific islands including Hawaii, prior to record history. Westward, banana possibly followed the major trade routes that transported other fruits, and is known to have arrived in east Africa around 500 A.D. Bananas were not carried to Europe until the 10th century and Portuguese traders obtained it from West Africa during the age of discovery. Plants were taken from West Africa to the Canary island and South American in the 16th century, and spread throughout the Caribbean in the 16th – 17th centuries. Bananas are now grown pantropically in 130 countries, more than any other fruit crop in the world.

According to the Food and Agricultural Organization (FAO) statistics (2002), banana is grown in 130 countries worldwide and produced 69,832,378 MT. and production has increased about 40% in
the last decade whereas plantains are grown as a staple food in 52 countries worldwide on about 12.5 million acres. Banana covers about 11 million acres, one of the largest areas devoted to a single fruit crop. Worldwide, the average yield is about 13000 lbs/acre. The top 10 countries, according to FAO produced (% of world production) banana fruits are as follows-


The chief banana growing states in India are- Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, West Bengal and Assam. Banana is one of the major fruit horticulturally important in Assam. Besides the cultivated varieties of banana, one of the varieties is grown in wild condition in Assam (Hotter & Thomson, 1958, cited by Dutt, 1979). Some of the cultivated banana varieties of Assam are – Mālbhog, Chenichampā, Jāhāji, Monohar, Bhimkol, Agniswar, Baratmani, Digjwa, Jātikol, Kācchkol, Kāchelupa, Tulsi, Amrit Sagar, Manuhā, Pithaguri, Bhāttākol, etc. (Dutt, 1979). Out of these, the most widely cultivated varieties of banana in the Nalbari districts are –‘Jāhāji’ (AAA, Dwarf Cavendish subgroup), ‘Borjāhāji’
Banana, botanically named “Musa paradisiaca” L. belongs to the family of Musaceae in the order Scitamineae. The family is characterised by leaves and bracts spirally arranged; male and female (hermaphrodite) flowers separated within one inflorescence; fruit is a many-seeded berry. Musaceae is a relatively small family with only 5 genera and almost 150 species. Banana is large, herbaceous monocots, reaching 25 ft in some cultivars, but generally 6-16 ft tall in cultivations. The ‘trunk’ or pseudostem is not a true stem, but only the clustered, cylindrical aggregation of leaf stalk bases. Leaves are among the largest of all plants, becoming up to 9 ft long and 2 ft wide. Margins are entire and venation is pinnate. A banana plant bears fruit 10-12 months after planting. According to Morton (1987), the climate suitable banana climate for banana plantation is a mean temperature of 26.67°C (80°F) and mean rainfall of 4 inch (10cm) per month. There should not be more than 3 months of dry season. The inflorescence is a spike originating from the rhizome. Initially, it appears above the last leaves in an upright position, and consists of a large, purple, tapered bud. As the bud opens, the narrow, white, tubular, toothed flowers are revealed, clustered in whorled double rows along the stalk,
each cluster covered by a thick, purple, hood like bract. The bract falls off from the first hands in 3-10 days. Female flowers, with interior ovaries, occupy the lower 5-10 rows on the stalk, with neuter or hermaphrodite flowers in the centre, and males at the top. Male flower and bracts are shed immediately after opening. An epigynous berry, fruits are borne in ‘hands’ of upto 20 fruits, with 5-20 hands per spike. Fruits appear as angled, slender, green ‘fingers’ during growth reaching harvest maturity in 90-120 days after flowers opening. Fruits can be harvested when about 75% mature, as angles are becoming less prominent and fruits on upper hands are light- green in colour. The optimum temperature for storage and transport is 13-14°C (56-58°F) for green fruits and for ripe ones 15-20°C (59-68°F) and the relative humidity 90-95% (Kader, 1985). Most commercial cultivars of banana require exposure to 100-150ppm ethylene for 24-48 hours at 15-20°C (59-68°F) and 90-95% relative humidity to induce uniform ripening.

Banana fruits provide a more balanced diet than many other fruits. Banana satisfies the definition of a good food, i.e., one that contains the required proportions of nutritive constituents, easily digested and absorbed and all this at reasonable cost. Banana is a good source of vitamin C (Chandler, 1995). The standard food value per
100g of the edible portion of fruit cited by Morton (1987) is as follows:

Calories- 65.5-111g.
Moisture (Water) 68.8-78.1g
Protein- 1.1-1.87g.
Fat- .016-0.4g.
Carbohydrates- 19.33-25.8g.
Fiber- 0.33-1.07g.
Ash -0.60-1.48g.
Calcium –3.2- 13.8mg.
Phosphorus- 16.3- 50.4mg.
Iron-0.4-1.50mg.
β-Carotene-0.006-0.151mg.
Thiamine-0.04-0.54mg.
Riboflavin-0.05-0.067mg.
Niacin-0.60-1.05mg.
Ascorbic acid (vitamin-C)- 5.60-36.4mg.
Tryptophan-17-19mg.
Methionine-.7-10mg.
Lysine-58-76mg.
The major sugar present in banana fruits is sucrose, glucose and fructose. The organic acid present in banana fruits are - malic acid, citric acid (Steward et al., 1960). Besides these, 14 oxoacid are also present in banana. Lulla and Johar (1954) have found citric acid, malic acid, boric acid, tartaric acid, acetic acid and butaric acid in two varieties of Brazilian bananas. Banana is one of the most popular fruits in India where it has been the food of sages (sadhus) since ancient times. In Assam as well as in South India, both the plantain and the fruits are used extensively in all auspicious occasions such as wedding, festivals and for worship. It is relatively inexpensive and is within the reach of all classes of buyers. Every part of the banana plant is used. There are many different products which can be made from banana fruits- alcohol, banana juice, chips, jams and jellies, banana figs, powder, flour, osmotic dehydration (for dairy, confectionary and breakfast cereal industries) and starch (Thomson, 1995). Besides these, the other parts of the banana plant are used for various purposes. Like in South India and Africa, the core of the pseudostem is also used as a vegetable in Assam and it is popularly known as 'Pachala'. The main bud or heart of banana bunches is also used as a vegetable in India, Thailand, Malaysia, Indonesia and Philippines. Banana plant yields a good fibre. Species such as *Musa textilis* are well known for
their strong fibre qualities. This fibre can be made into strong rope or Abaca cloths. The fibre can be mixed with wood fibres to make paper; novelty items such as notepads, envelopes and wrapping paper are sold in Costa Rica. Fibre production and paper making from fibre are commercial possibilities. Waste pseudostems of banana of all types have been used for manufacturing paper boards at the Tamil Nadu Agricultural University. The juice from the pseudostem can be used in dyes as it has the property of a permanent stain. Banana leaves are very popular in South India and Africa as dinner plates and wrapping materials. In Latin America, it is a common practice during rains to hold a banana leaf by the petiole, upside-down, over one’s back as an umbrella or raincoat. The rhizomes of the plants bear various alkaloids. Ash from burned leaves sheaths and stem is used to prepare food item popularly known as “kola khar” by the Assamese people.

Bananas have a number of medicinal uses. Many of the uses are poorly documented, but include treatment for ailments of the skin, back, and blood, headache, fever and flu, both diarrhea and constipation and several others including gray hair and syphilis. Simmonds mentions that the most spectacular use is in the control of colic disease in children, a condition which manifests itself as an intolerance of carbohydrate but in which bananas can be easily
digested (Madhava Rao, 1984). Bananas contain moderate amounts of potassium, although the utility of bananas for restoring electrolytes or regulating blood pressure may be overstated. Banana ash is rich in alkaline salts and therefore can check acidity in stomach, heart-burn and colic. In Africa, the juice of the pseudostem is taken for increasing milk production of mother.

Post harvest diseases of fruits are responsible for causing losses because of the perishable nature of the produce and tropical conditions of the country (Dharam Vir, 1977). It is generally known that air borne fungal spores are responsible for deterioration of all kinds of fruits, particularly the sharp deterioration of banana fruits. It has been reported that post harvest diseases of banana fruits are responsible for causing losses ranging 5-15% each year (Tandon, 1967). Harvey, (1978) reported that post harvest losses have been estimated within the range 10-30% per year despite the use of modern storage facilities and techniques.

The publication of several papers on Indian banana disease by Indian and foreign pathologists have resulted in a steady progress in the research works of banana diseases. But in Assam particularly, as a whole, the research works on banana diseases are either completely ignored or partially studied. It has been recorded that post harvest
diseases of banana fruits are responsible for causing losses in the market of Assam. Whereas scientists and researchers have given scant attention to market pathology in Assam, post harvest losses have not been investigated into in detail. Post harvest diseases of banana are responsible for heavy economic losses in the Tihu area in Nalbari districts of Assam. Therefore, surveys have been taken up with aspects like fungi associated with post harvest decay, environmental factors influencing fungal spoilage, effect of carbon and nitrogen sources on the growth of the fungal pathogen, effect of sugar and vitamin C during pathogenesis and measures to control them. For studying succession of fungal contaminants at monthly intervals, the following two varieties of banana which are widely cultivated in this area and are in demand in the market have been selected-

1. ‘Chenichampa’ (AAB).
2. ‘Mālbhog’ (AAB, ‘silk’).

The district of Nalbari lies between $25^0 43' - 26^0 53' \text{ N }$ latitude and $90^0 39' - 92^0 11' \text{ E }$ longitude in the state of Assam in the eastern part of India. Geographically it is bounded on the north by Bhutan Territory; on the east by Kamrup district (Rural); on the south by the river Brahmaputra and on the west by Barpeta district. The whole part of the district consists of a wide fertile alluvial plain besides some
lowland area and banana plant is extensively cultivated in both areas. Range of temperature, relative humidity (RH) and rainfall of the area varies widely. Banana is essentially a humid tropical plant, coming up well in regions with a temperature range of 10° to 40° C. A mean temperature of 80° F (26.7°C) and about 100mm (four inches) of rain per month are considered satisfactory.

Banana and also its plantation are attacked by a great many diseases affecting all parts of the plant and, as a result, the production of fruit is rather low. The causes of the diseases may be fungi, bacteria, viruses, nematodes or environmental factors. Common diseases of banana caused by fungi are- panama disease, black leaf spot, sigatoka or leaf spot diseases, crown-rot, anthracnose, black-heart diseases, diamond- spot, pitting diseases, squirter disease, black leaf streak diseases, leaf- spot disease, rhizome rot, tip drying, brown circular spot of fruits, fruit rot of banana, dark-brown fruit spots, finger-stalk rot, brown specks on fruits, cigar-end rot of fruit, brown spot disease of banana fruit, etc. known to the cultivators.

It has been reported that some of the diseases of apples, banana, guava, mango, papaya, pears, tomato etc. have been studied at different centres by many researchers and some of the organisms associated with their diseases have had considerable influence on
different aspects of cultivation, nutritive value, harvesting, transit and transshipment, storage and diseases of banana and their control. Major economic part of the banana plant is the fruit only and the fruit is heavily infected by different pathogens, mainly fungal pathogens, the cultivators and the retail sellers are facing heavy economic losses on account of fruit rotting during cultivation as well as in storage. The environmental factors such as temperature and relative humidity have profound influence on the fruit diseases and their severity. Therefore, much more attention has been paid to studies on the economic aspect of fungal disease encountered during storage condition. The effects of temperature and relative humidity on the decay of mango, banana, papaya, guava, citrus, apples, pomegranate and other tropical fruits have been studied by various workers (Edney, 1964; Srivastava et al., 1965; Badger, 1965; Bhargava et al., 1966; Kaiser and Lukezic, 1966; Brown, 1975 Narania and Reddy, 1978; Wadia et al., 1986; Singh et al., 1995; Banyal and Tyagi, 1997).

Among the pathogens in the banana, *B. theobromae* can grow at a temperature at 25°C; whereas in case of *Colletotrichum musae* 10-35°C and 30°C is optimum temperature (Tandon, 1967); Singh et al., (1995) observed that the maximum rotting of banana fruits by different fungi were at 25°C -30°C. However, further increase of
result in reduced infection (Kaiser and Lukezic, 1966). Bonner (1948) studied the temperature and humidity requirements of *Aspergillus niger* and found that the optimum conditions for growth are at relative humidity 93% and at a temperature near 40°C; at 100% relative humidity the optimum temperature is near 30°C. Misra and Singh (1962) observed that the optimum temperature for the development of anthracnose on ripe banana fruits could be incited at 85.7% to 100% relative humidity. Badger (1965) studied the influence of relative humidity on fungi causing crown rot of boxed banana. Khanna and Chandra (1975) showed that a high relative humidity is necessary for the post harvest rots of banana incited by *Fusarium moniliforme* and *F. roseum*.

Wardlaw (1972) has traced the source of infection of most of the major post harvest diseases of banana *Fusarium roseum, Verticillium theobromae* and *Gloeosporium musarum* were isolated from the crowns of fruits shipped in box from Central and South America, (Greene and Goos, 1963). Again Srivastava *et al* (1965) has found common fruit rot fungi of banana like *Colletotrichum musae, Botryodiplodia theobromae, Alternaria alternata, Deightoneiella torulosa, Fusarium oxysporum* and *Nigrospora oryzae*. Berg (1968) has established that “diamond-spot” of banana fruits originates from
the plantains where the casual organism *Fusarium roseum* is found in abundance. Dhingra *et al* (1970) has reported cigar-end disease of banana caused by *Verticillium theobromae* (Turc) in India. Meredith (1971) has listed 25 fungi and many unidentified bacteria associated with the crown rot of banana.

It is known that the development of a progressive lesion depend on whether conditions at the point of entry are suitable for secretion of cell-wall degrading enzymes. The importance of cell wall degrading enzymes in the development of rot of fleshy fruit is well established. In post harvest diseases, a common symptom is the disorganization of host tissues by enzymes of pathogen origin—the production of polygalacturase and pectic lysase by *Colletotrichum musae* and *Fusarium semitectum* with the fruit decay of banana (Shillingford and Sinclair, 1980). Chang *et al* (1987), has studied the postharvest penetration of the cuticle of ripe banana fruits and subsequent colonization process by *Colletotrichum musae* which is suggestive of the secretion of an extracellular cutinase by the pathogen. The appearance of carboxylase and adolase activity during ripening in the banana indicates that a synthesis of these enzymes occurs and leads to and support pathogens (Tager and Biale, 1957). The ability to produce pectinesterase is widespread among parasitic microorganisms.

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Srivastava et al (1959) reported *Rhizopus stolonifer* secretes little or none in media containing pectin or extracts from plant tissues.

Needless to say that the control of plant disease is of highest importance as it is concerned with the full protection of production of economic and commercial crops and also for checking post-harvest losses due to attack of fungal pathogens. Besides biological control of plant diseases, chemical control (by using fungicides and antibiotics) has now-a-days been used quite effectively. Several methods including use of fungicides, antibiotics, storage at low and high temperature and growth regulator have been suggested by various workers to control post harvest decays of fruits and vegetables (Dastur, 1916; Eckert and Kolbezen, 1964; Eckert and Sommer, 1967; Thakur and Chenulu, 1970; Long, 1970a; Meredith, 1971; Griffie and Burden, 1974; Khanna and Chandra, 1976; Spalding and Hardenburg, 1971; Slabaugh and Grove, 1982; Ram and Vir, 1984 Eckert, 1990). The growth and development of post harvest diseases have revealed several possible strategies that are helpful in reducing losses on decay in fruits or vegetables.

It is generally known that the plant pathologists mostly confine themselves to the study of the diseases of various crop plant or cash crop. Most of the workers have mentioned the symptoms of various
diseases, their casual organisms and occasionally methods of their control. Now-a-days, plant pathologists are paying much more attention towards post harvest diseases of fruits and vegetables. Post harvest losses can be estimated in their several aspects like old packaging methods, storage, transit, marketing facilities and fungal attack as suffered by the growers, whole sellers and retail sellers. Out of these, post harvest losses are more due to fungal infection. So that it is necessary to stress to find out the ways and means of saving the fruits and vegetables from infection by various pathogenic organisms.

Therefore, the aim of the present investigation is to determine the fungal pathogens causing banana fruit rot in storage condition of Tihu area and to study certain pathological and physiological growth of the pathogen in post harvest stage, biochemical aspects of infection and as far as possible to study the sources of infection and look for measures to control them.